STIF

7.7 - 1 0.0.3.8. II
CR-149139 DRAFT
EROS

"Made available under NASA sponsorship
in the interest of early and wide dissemination of Earth Resources Survey
Program information and without liability
for any use made thereof."

29810

# WATER RESOURCES INVESTIGATION IN WEST PAKISTAN WITH THE HELP OF ERTS IMAGERY - SNOW SURVEYS

(E77-10038) WATER RESOURCES INVESTIGATION
IN WEST PAKISTAN WITH THE HELP OF ERTS
IMAGERY: SNOW SURVEYS (Pakistan Water and
Power Development Authority) 48 p
HC A03/MF A01 CSCL 08H G3/43

N77-14544

Unclas
00038

## CH. MOHAMMAD UMAR

CHIEF ENGINEER, HYDROLOGY



AUGUST, 1976

W.A.P.D.A.
(Pakistan Water and Power Development Authority)
in association with SUPARCO and NASA

29810

DRAFT

29810

# WATER RESOURCES INVESTIGATION IN WEST PAKISTAN WITH THE HELP OF ERTS IMAGERY - SNOW SURVEYS

CH. MOHAMMAD UMAR,
Chief Engineer, Hydrology

August, 1976

WAPDA (Pakistan Water and Power Development Authority)
in association with SUPARCO and NASA.

CONTENTS

## ILLUSTRATIONS

# WATER RESOURCES INVESTIGATION IN WEST PAKISTAN WITH THE HELP OF ERTS IMAGERY - SNOW SURVEYS

CH. MOHAMMAD UMAR,
Chief Engineer, Hydrology,
WAPDA

A B S T R A C T

Pakistan depends upon its agricultural produce to sustain its population. The pre-monsoon period March to June, is critical in respect of water supply in the rivers. This is also the period when the snow pack melts on the mountains and feeds the rivers. The two large reservoirs Mangla and Tarbela regulate the available water supply. If this water supply can be predicted for April to June, the reservoirs can be operated with confidence. High resolution LAND-SAT 2 Imagery of the snow-covered area in Upper Indus Basin has been obtained through NASA for the period January to June, 1975. From this imagery snow line maps have been prepared of selected basins with the help of Zoom Transfer-scope and Colour Additive Viewer. From these maps snow covered area has been planimetered with respect to time and hydrographs of the snow melt have been plotted for the period of melt from the data supplied by the stream-gauging network. Only one season's imagery has been received; therefore no regression equation has been tried. However, during the coming years this relation shall be developed. It is felt that snow line tracing and measurement with planimeter method can be successfully applied to the LAND-SAT Imagery of Upper Indus Basin.

# WATER RESOURCES INVESTIGATION IN WEST PAKISTAN WITH THE HELP OF ERTS IMAGERY - SNOW SURVEYS

CH. MOHAMMAD UMAR,
Chief Engineer, Hydrology,
WAPDA
(Pakistan Water and Power Development Authority)
Lahore, Pakistan, in association with SUPARCO
and NASA.

## INTRODUCTION

Pakistan is basically an agrarian country depending upon the agricultural produce to sustain its population. The pre-monsoon period March to June is critical in respect of the water supply in the rivers. The Rabi crops (Wheat, Oil-seeds, etc.) mature in April and Kharif crops (Sugarcane, Cotton, etc.) are sown during April - May. This is the time when almost no rainfall occurs and land depends entirely on the supply of water in the rivers for irrigation through the vast network of canals. The available water supply has to be rationed and used carefully to derive the optimum benefits from the irrigated land. The two large reservoirs that Pakistan has built at Mangla and Tarbela are generally at the lowest level in April having been continuously depleted during the winter. Yet further releases are to be made during the spring.

Rivers of the Indus Basin rise in the mountains with elevations as high as 8,500 meters. These mountains are covered with snow during winter (January to March). The snow starts melting towards the end of March and continues

through the summer. River flows consist mostly of the snow-melt during this period. If flows can be predicted with some accuracy, the reservoir operations can be planned with confidence and canal system can be run on rational basis. Such predictions cannot be made without snow surveys. The ground methods of snow surveys are expensive, time-consuming and difficult. Luckily with the advent of Land-satellites it has become possible to map the earth's surface at fixed intervals. Land-satellite 1 and Land-satellite 2 scan the earth every 18 days each. These satellites produce high resolution images of the earth's surface which when interpreted properly give the area of snow cover. The snow cover area can be related with the snow-melt run-off at strategic points. This can give a base for predicting the snow-melt run-off.

## STUDY AREA AND DATA SOURCES

WAPDA has entered into an Agreement with NASA (National Aeronautics and Space Administration), through SUPARCO (Pakistan Space and Upper Atmosphere Research Committee) in May 1975 - "29810, Water Resources Investigation in West Pakistan with the help of ERTS Imagery - Snow Surveys". Under this agreement NASA had to supply Land-Sat 2 imagery of the project area beginning January 1975. The project area is bounded by the coordinates 33.00N to 37.00N and 71.00E to 78.00E (Figure - 1). So far NASA has supplied for the period January to June 1975 the following imagery:-

| S.No | Scene ID No. | Date | CENTRE POINT | | Band |
|---|---|---|---|---|---|
| | | | Lat. N | Long. E | |
| (1) | (2) | (3) | (4) | (5) | (6) |
| 1. | 2023-04554 | 14-2 | 34°-31' | 75°-20' | 4,5 |
| 2. | 2025-05071 | 16-2 | 34°-28' | 72°-25' | 4,5,7 |
| 3. | 2025-05064 | 16-2 | 35°-54' | 72°-52' | 4,5,7 |
| 4. | 2025-05062 | 16-2 | 37°-20' | 73°-19' | 4,5 |
| 5. | 2026-05125 | 17-2 | 34°-29' | 70°-59' | 4,5,7 |
| 6. | 2026-05123 | 17-2 | 35°-55' | 71°-25' | 4,5,7 |
| 7. | 2026-05120 | 17-2 | 37°-21' | 71°-53' | 4,5,7 |
| 8. | 2040-04501 | 3-3 | 33°-13' | 76°-19' | 4,5,7 |
| 9. | 2040-04495 | 3-3 | 34°-39' | 76°-46' | 4,5,7 |
| 10. | 2043-05070 | 6-3 | 34°-34' | 72°-26' | 4,5,7 |
| 11. | 2044-05122 | 7-3 | 35°-56' | 71°-26' | 4,5,7 |
| 12. | 2044-05120 | 7-3 | 37°-22' | 71°-54' | 4,5,7 |

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| 13. | 2061-05065 | 24-3 | 34°-31' | 72°-26' | 4,5,7 |
| 14. | 2061-05062 | 24-3 | 35°-57' | 72°-54' | 4,5,7 |
| 15. | 2061-05060 | 24-3 | 37°-23' | 73°-21' | 4,5,7 |
| 16. | 2062-05213 | 25-3 | 34°-31' | 71°-01 | 4,5,7 |
| 17. | 2062-05121 | 25-3 | 35°-57 | 71°-27' | 4,5,7 |
| 18. | 2062-05114 | 25-3 | 37°-22' | 71°-55' | 4,5,7 |
| 19. | 2077-04552 | 9-4 | 34°-33' | 75°-14' | 4,5,7 |
| 20. | 2078-05010 | 10-4 | 34°-32' | 73°-54' | 4,5,7 |
| 21. | 2078-05004 | 10-4 | 35°-58' | 74°-21' | 4,5,7 |
| 22. | 2079-05065 | 11-4 | 34°-29' | 72°-26' | 4,5,7 |
| 23. | 2079-05062 | 11-4 | 35°-55' | 72°-53' | 4,5,7 |
| 24. | 2079-05060 | 11-4 | 37°-21' | 73°-21' | 4,5,7 |
| 25. | 2080-05123 | 12-4 | 34°-28' | 70°-53' | 4,5,7 |
| 26. | 2095-04545 | 27-4 | 35°-52' | 75°-70' | 4,5,7 |
| 27. | 2095-04543 | 27-4 | 37°-17' | 76°-07' | 4,5,7 |
| 28. | 2096-05010 | 28-4 | 34°-26' | 73°-48' | 4,5,7 |
| 29. | 2096-05004 | 28-4 | 35°-51' | 74°-14' | 4,5,7 |
| 30. | 2096-05001 | 28-4 | 37°-17' | 74°-42' | 4,5,7 |
| 31. | 2098-05114 | 30-4 | 37°-10' | 71°-45' | 4,5,7 |
| 32. | 2116-05121 | 18-5 | 34°-23' | 70°-57' | 4,5,7 |
| 33. | 2116-05115 | 18-5 | 35°-49' | 71°-23' | 4,5,7 |
| 34. | 2130-04495 | 1-6 | 32°-59' | 76°-09' | 4,5,7 |
| 35. | 2131-04552 | 2-6 | 34°-33' | 75°-14' | 4,5,7 |
| 36. | 2131-04545 | 2-6 | 35°-47' | 75°-35' | 4,5,7 |

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| 37. | 2131-04543 | 2-6 | 37°-12' | 76°-03' | 4,5,7 |
| 38. | 2132-05010 | 3-6 | 34°-18' | 73°-42' | 4,5,7 |
| 39. | 2132-05001 | 3-6 | 37°-10' | 74°-35' | 4,5,7 |
| 40. | 2133-05065 | 4-6 | 34°-19' | 72°-15' | 4,5,7 |
| 41. | 2133-05062 | 4-6 | 35°-45' | 72°-42' | 4,5,7 |
| 42. | 2148-04500 | 19-6 | 33°-03' | 76°-08' | 4,5,7 |
| 43. | 2149-04550 | 20-6 | 35°-56' | 75°-34' | 4,5,7 |
| 44. | 2149-04543 | 20-6 | 37°-22' | 76°-07' | 4,5,7 |
| 45. | 2150-05002 | 21-6 | 37°-19' | 74°-35' | 4,5,7 |
| 46. | 2151-05060 | 22-6 | 37°-21' | 73°-10' | 4,5,7 |
| 47. | 2152-05124 | 23-6 | 34°-27' | 70°-48' | 4,5,7 |
| 48. | 2152-05121 | 23-6 | 35°-53' | 71°-15' | 4,5,7 |
| 49. | 2152-05115 | 23-6 | 37°-18' | 71°-42' | 4,5,7 |

Only this imagery has been analysed and used for this report. Imagery for the snow season 1976 is yet to be received from NASA.

## M E T H O D S



The images were put through Colour Additive Viewer and the Zoom Transfer-scope and the workable images were separated. The Indus Basin was then divided into eight sub basins given below and shown in Figures 2 to 9:-

| | | |
|---|---|---|
| 1. | Swat River near Kalam area | 780 sq. mi. |
| 2. | Chitral River at Chitral | 4,400 sq. mi. |
| 3. | Kunhar River at Naran | 400 sq. mi. |
| 4. | Indus River at Besham | 62,700 sq. mi. |
| 5. | Kishan Ganga River at Muzaffarabad | 2,810 sq. mi. |
| 6. | Jhelum River at Kohala | 9,610 sq. mi. |
| 7. | Hunza River at Dainyor Bridge | 5,080 sq. mi. |
| 8. | Gilgit River at Gilgit | 4,670 sq. mi. |

With the help of Zoom Transfer-scope and Colour Additive Viewer, overlays of all the sub basins were prepared for each day of the available images. On these overlays snow covered area was marked in colour and was calculated with a planimeter. Eighteen days per square mile river flows were tabulated. The percent snow-covered area and eighteen days per square mile river flows were plotted on a time base. These plots have been shown in Figures 10 to 17.

## RESULTS AND DISCUSSION

An examination of Figures 10 to 17 reveals that the snow cover increases as we travel from South to North. The snow starts melting earlier on the southern latitudes and stays longer on the northern latitudes. On the southern latitudes the snow starts melting towards the middle of February whereas in the northern latitudes the melting starts generally towards the end of March. Higher mountain peaks are encountered as we travel from South to North. In general, it can be assumed that snow melt starts about the first of April. By the end of June about 50% of the basin becomes free of snow. The remaining 50% of the snow cover keeps melting through the summer. Towards the end of August a recession starts in the snow melt hydrographs till it hits the base flow towards the end of October.

No attempt has been made at a regression equation; this cannot be done with one year's data. However, it is believed that a regression equation will ultimately emerge when four or five years data has been analysed. The regression equation is expected to be of the form of $R = aS + b$ where R is runoff in acre feet over a given period of time say 1st April to 30th June, S is the % snow cover on a given date say 1st of April, a and b are constants.

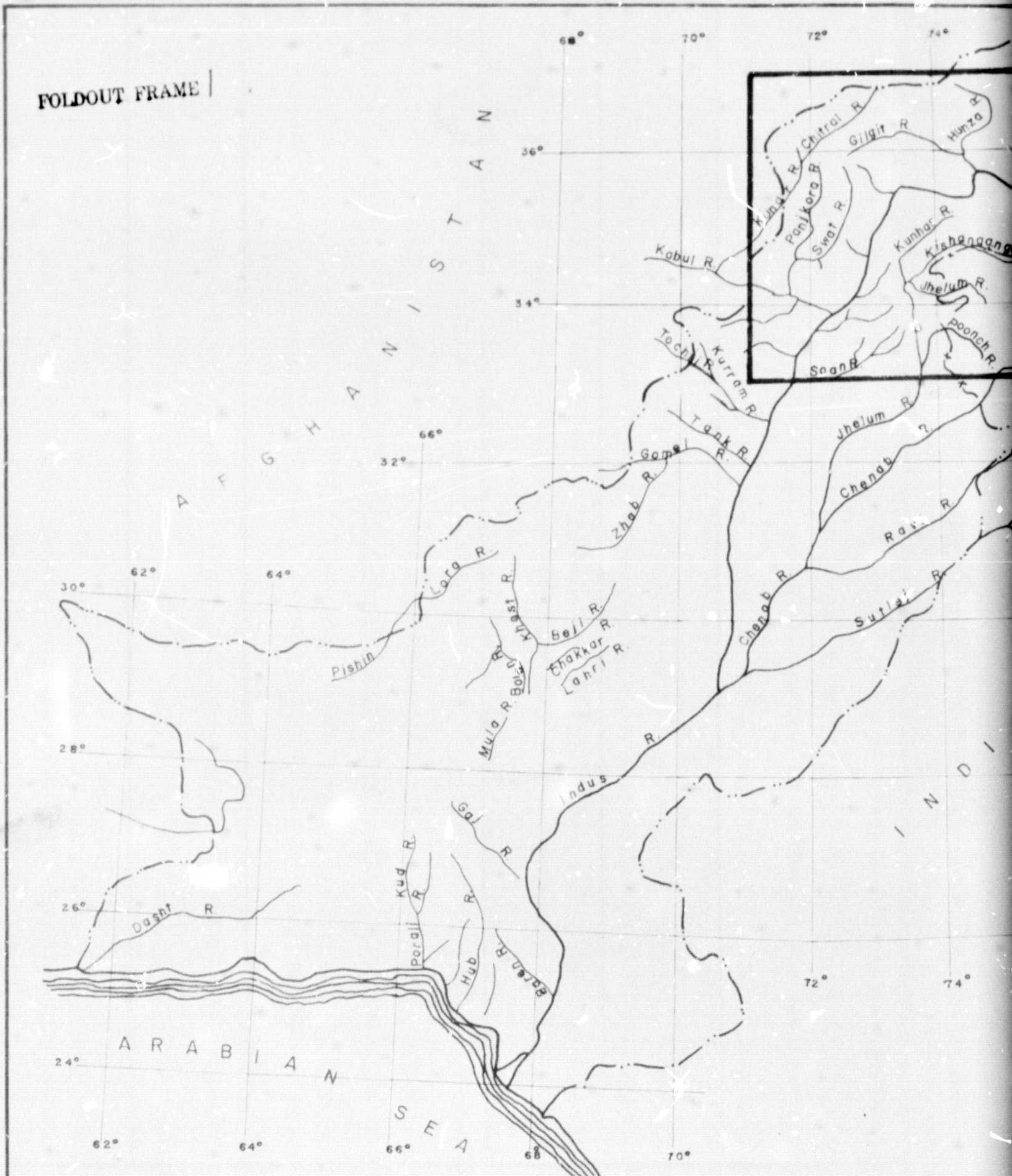
# C O N C L U S I O N

Figures 10 to 17 indicate that a relationship is possible between the snow covered area on a particular date and the resulting snow melt runoff during the subsequent period although snow depth and water equivalent have not been directly measured. The relationship is likely to take the form of a linear regression equation of the type $R = aS + b$. About 5 years data will be needed to confirm this conclusion.

## A C K N O W L E D G E M E N T S

The author is grateful to NASA for providing financial support and to EROS Data Centre for sending the imagery. The author is also grateful for the help SUPARCO provided by way of handling the correspondence and by making their instruments available for interpretation. The author is grateful to Surface Water Hydrology Project for supplying the run-off data. The author is in particular grateful to Sh. Mohammad Hussain, Co-Investigator, who spent long hours on the interpretation of the images.

FOLDOUT FRAME



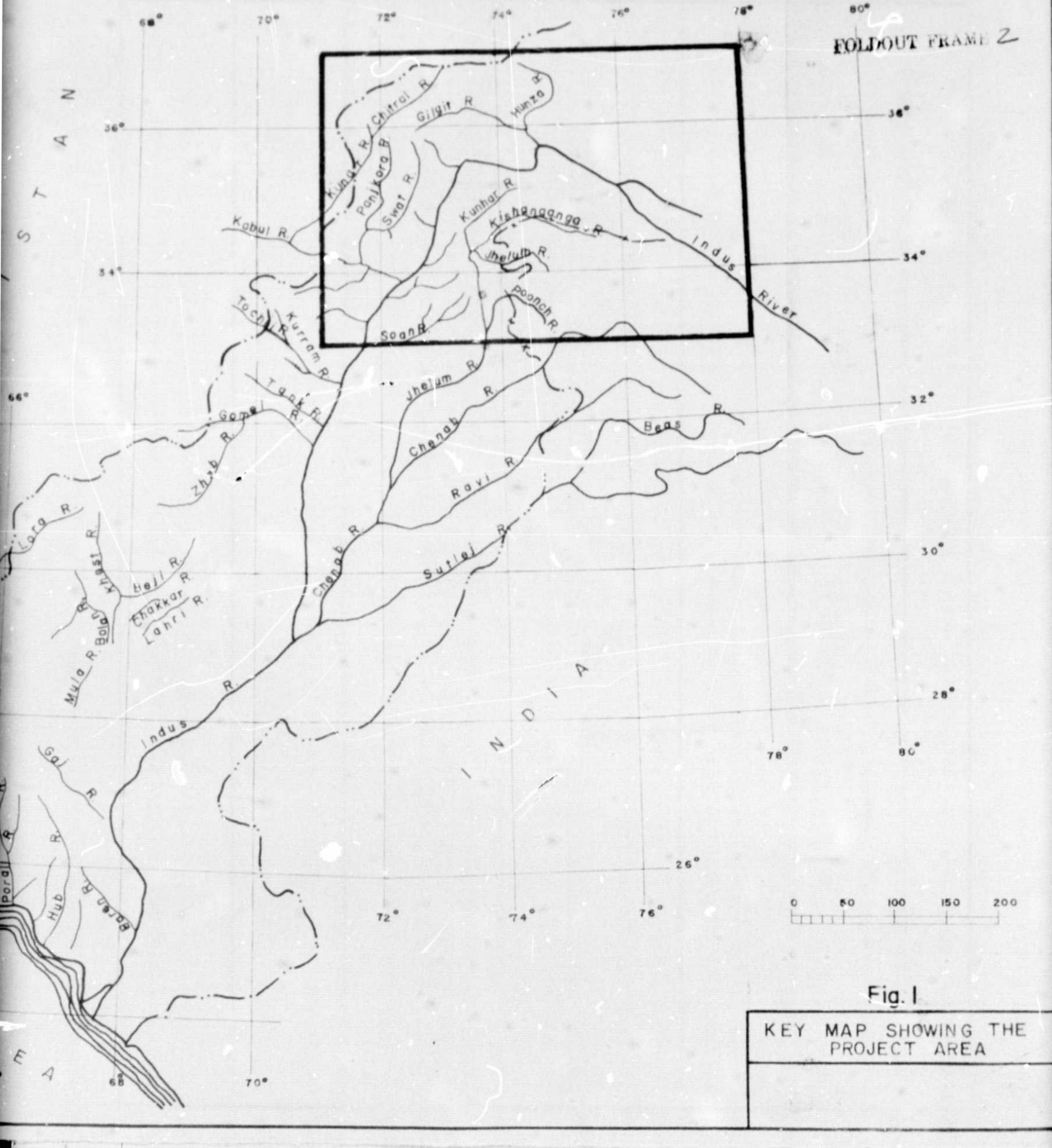
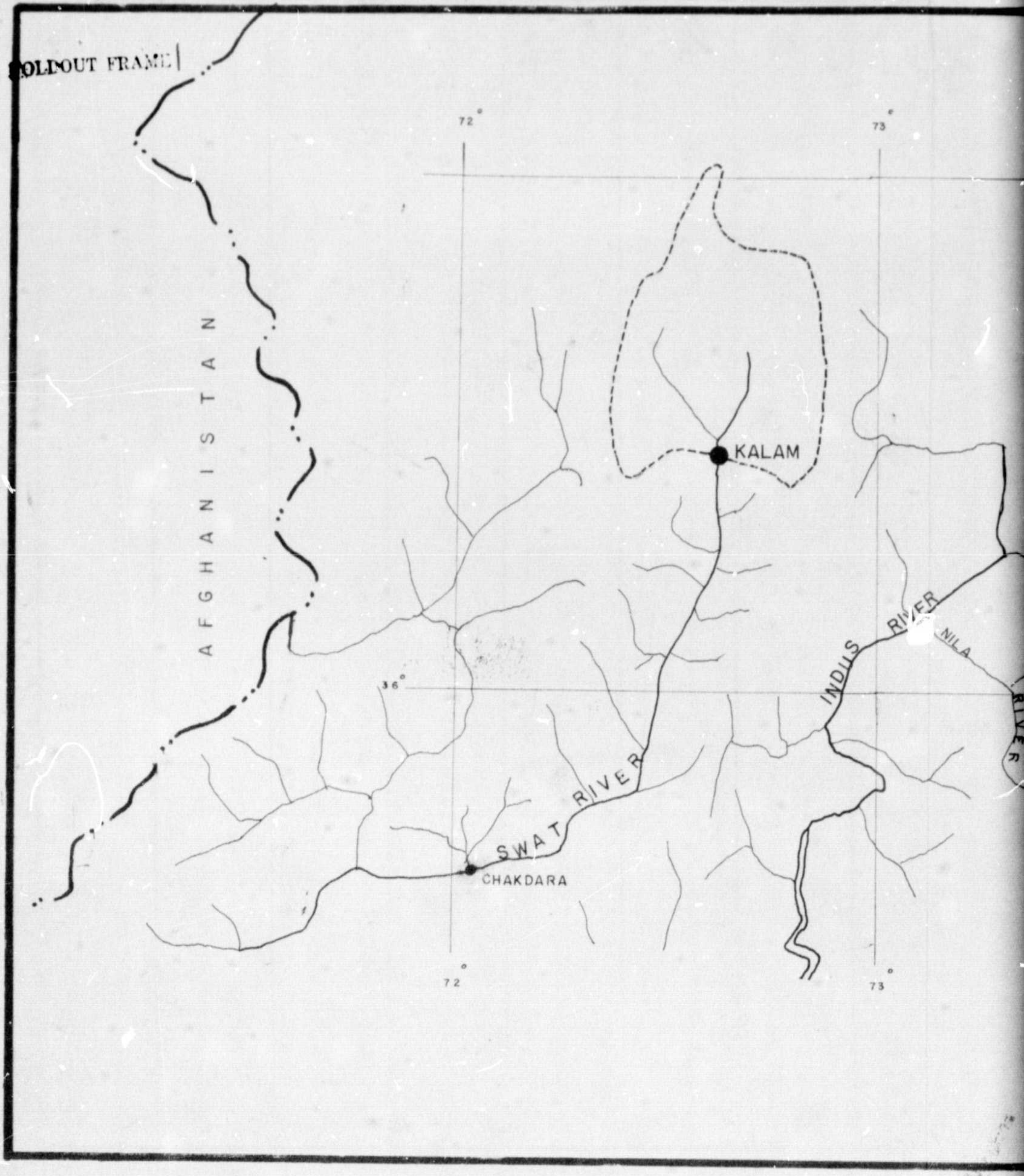



Fig. I

KEY MAP SHOWING THE PROJECT AREA

FOLDOUT FRAME



FOLDOUT FRAME 2

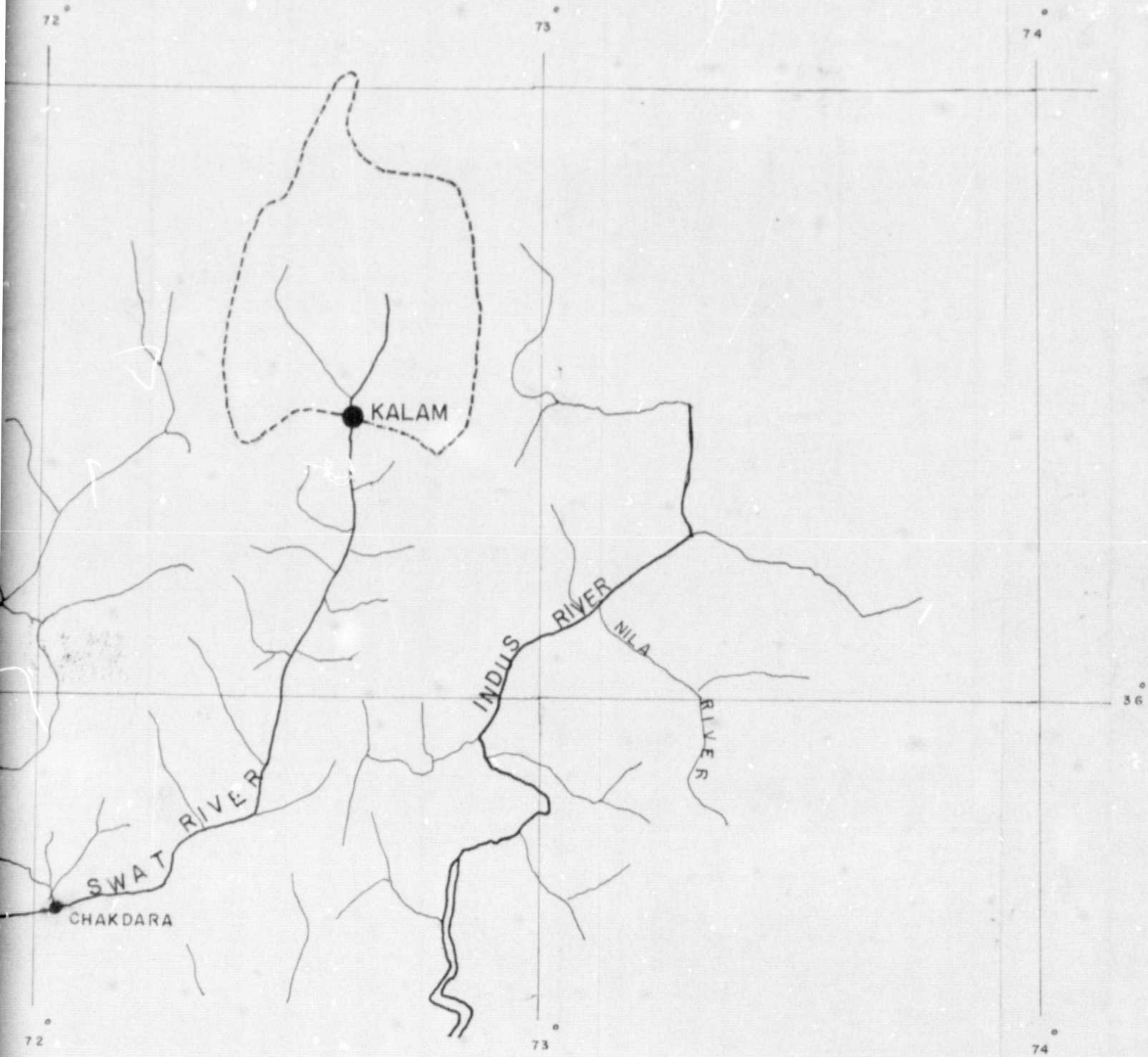
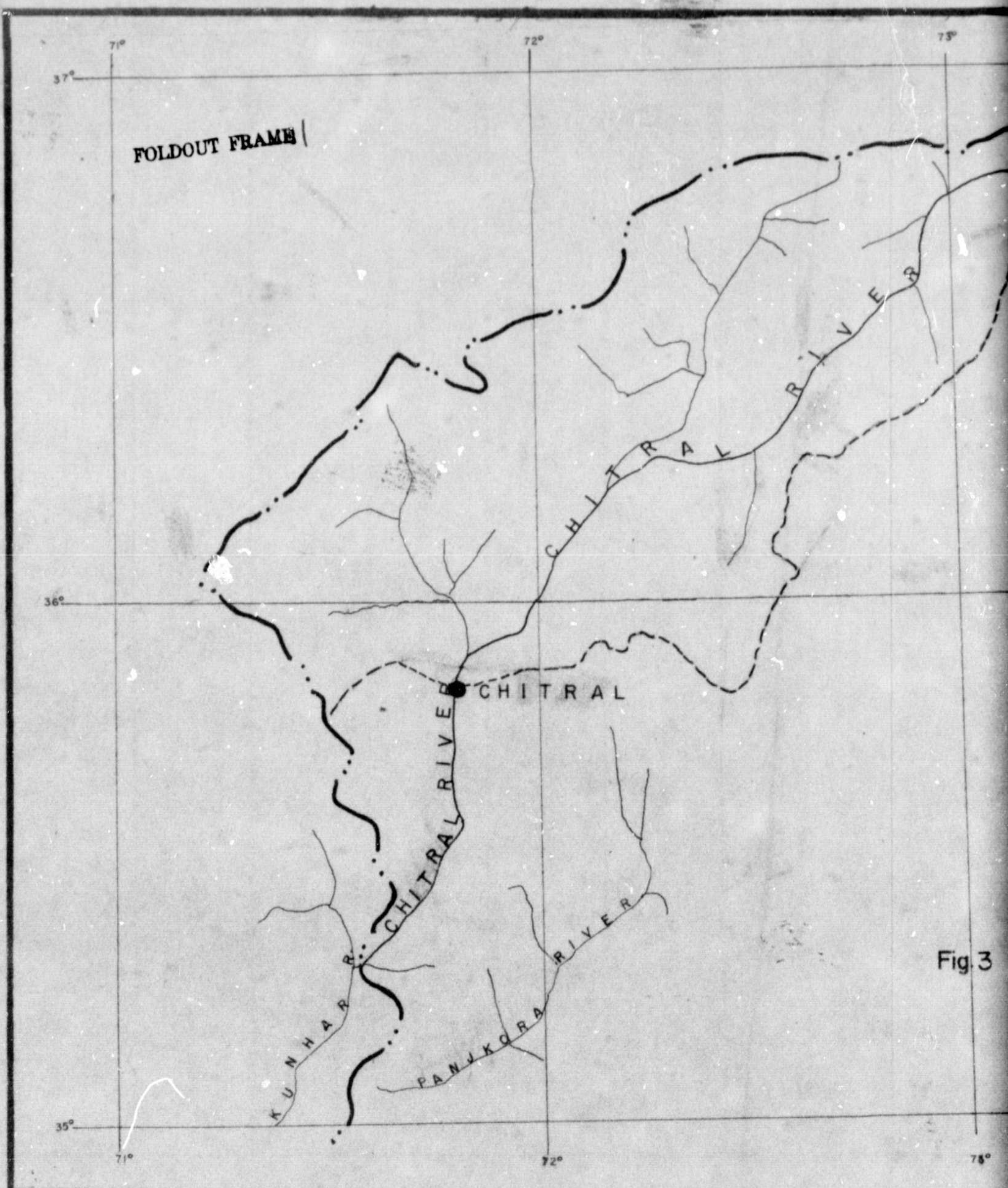



Fig. 2 SWAT RIVER NEAR KALAM

AREA = 780 Sq. Miles



FOLDOUT FRAME 1
71°
72°
73°
37°
36°
35°
CHITRAL RIVER
CHITRAL
CHITRAL RIVER
CHITRAL RIVER
KUNHAR R.
PANJKORA RIVER

Fig. 3

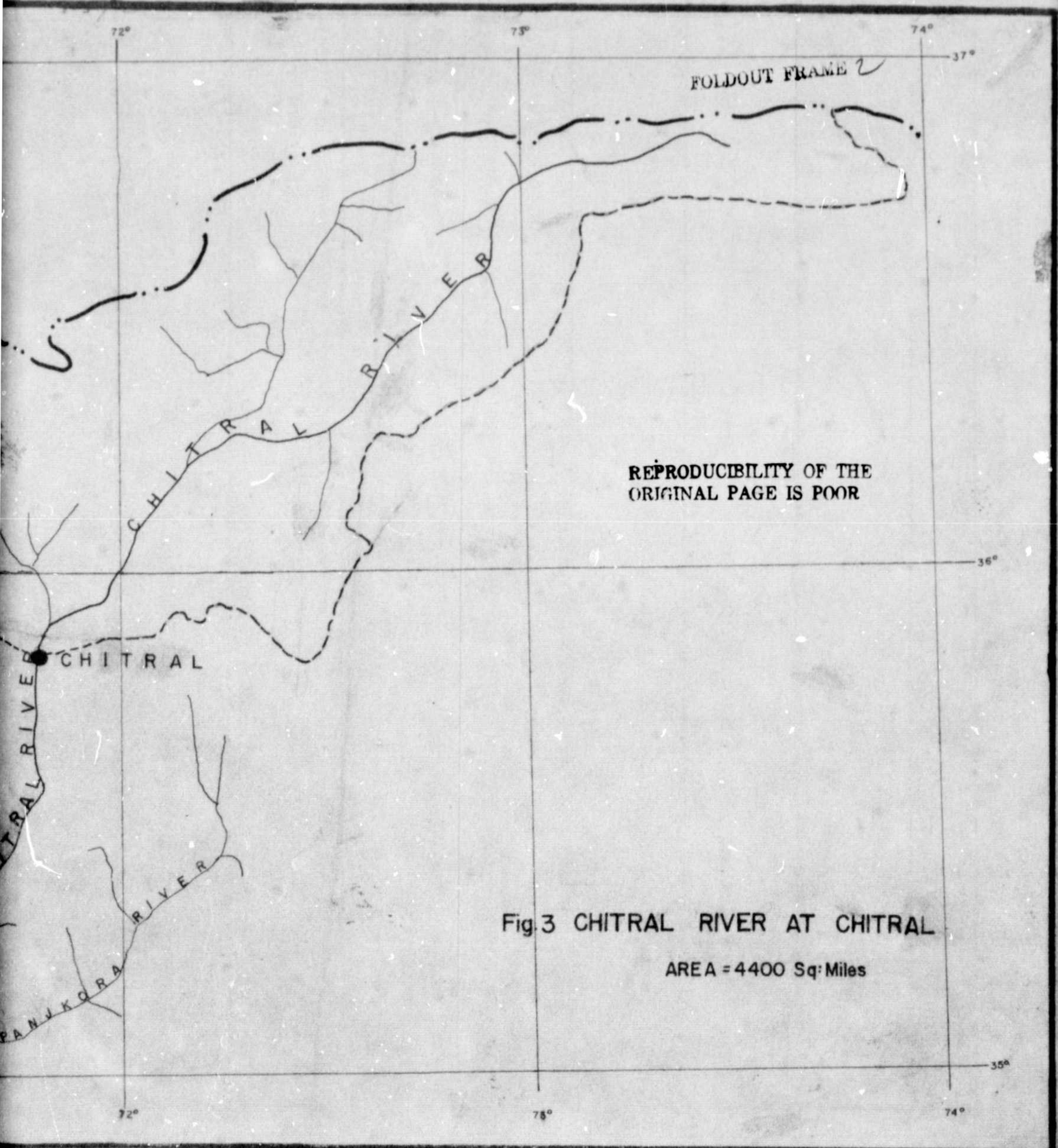
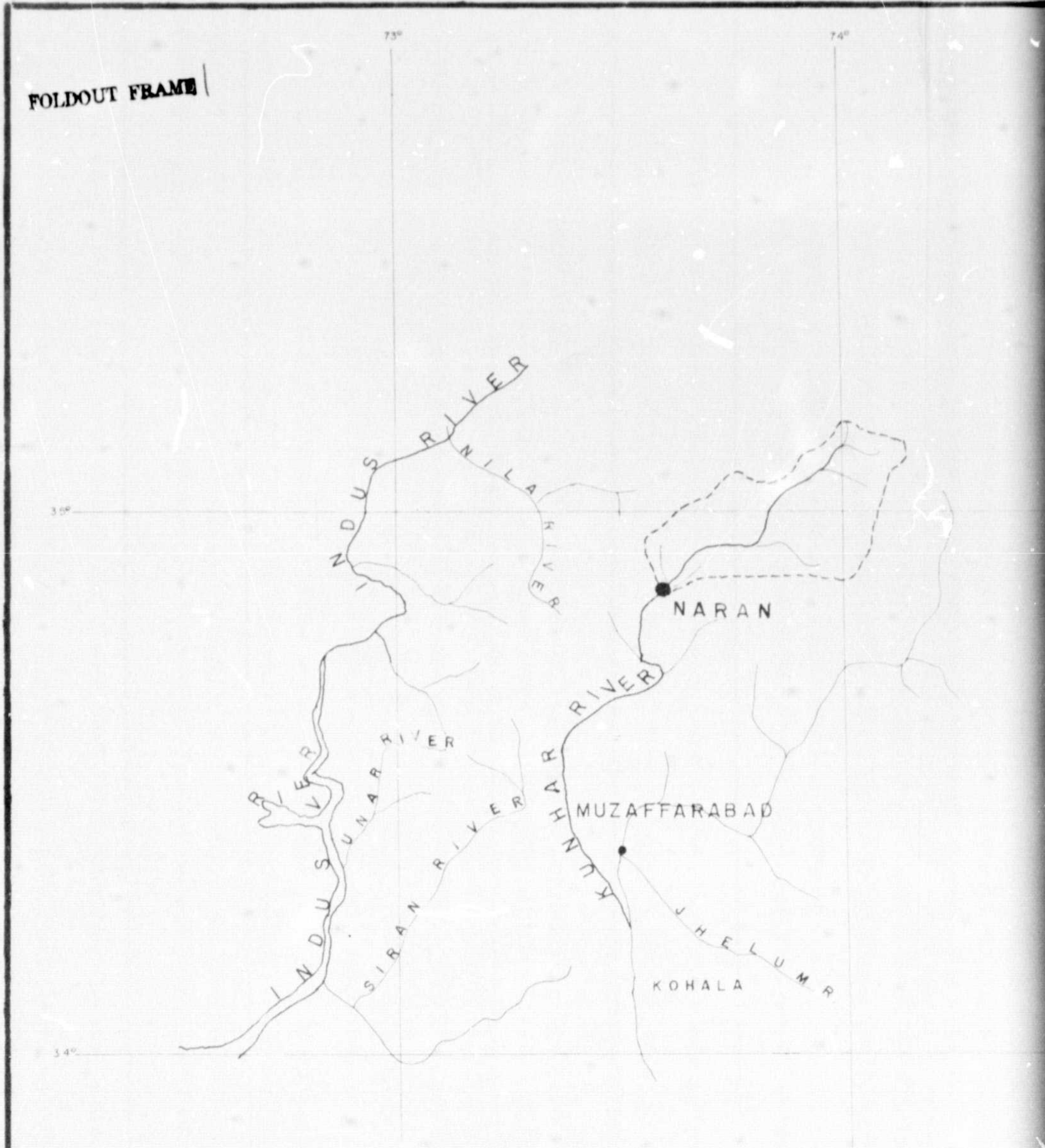





Fig.3 CHITRAL RIVER AT CHITRAL

AREA = 4400 Sq: Miles

FOLDOUT FRAME



FOLDOUT FRAME 2

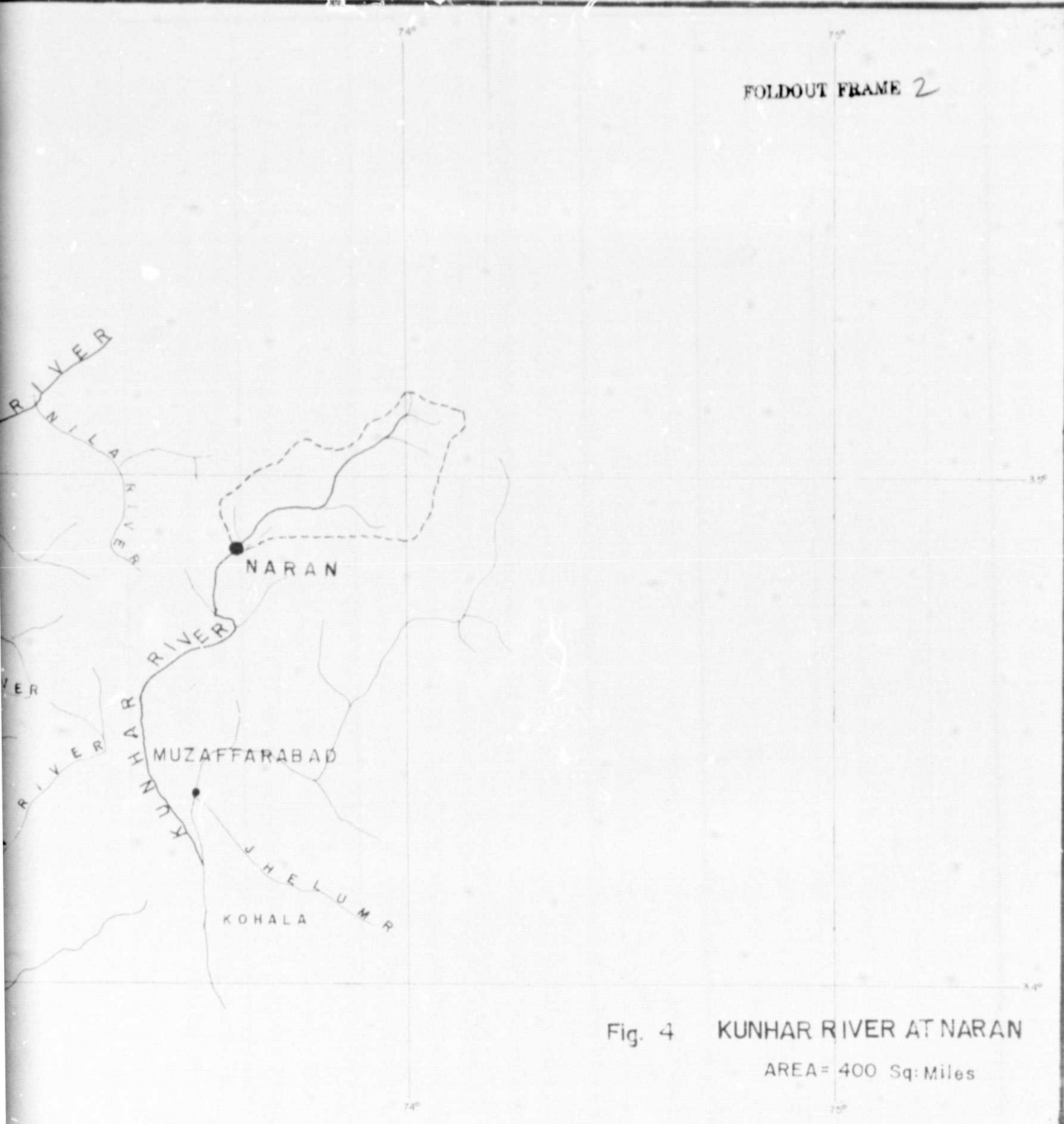
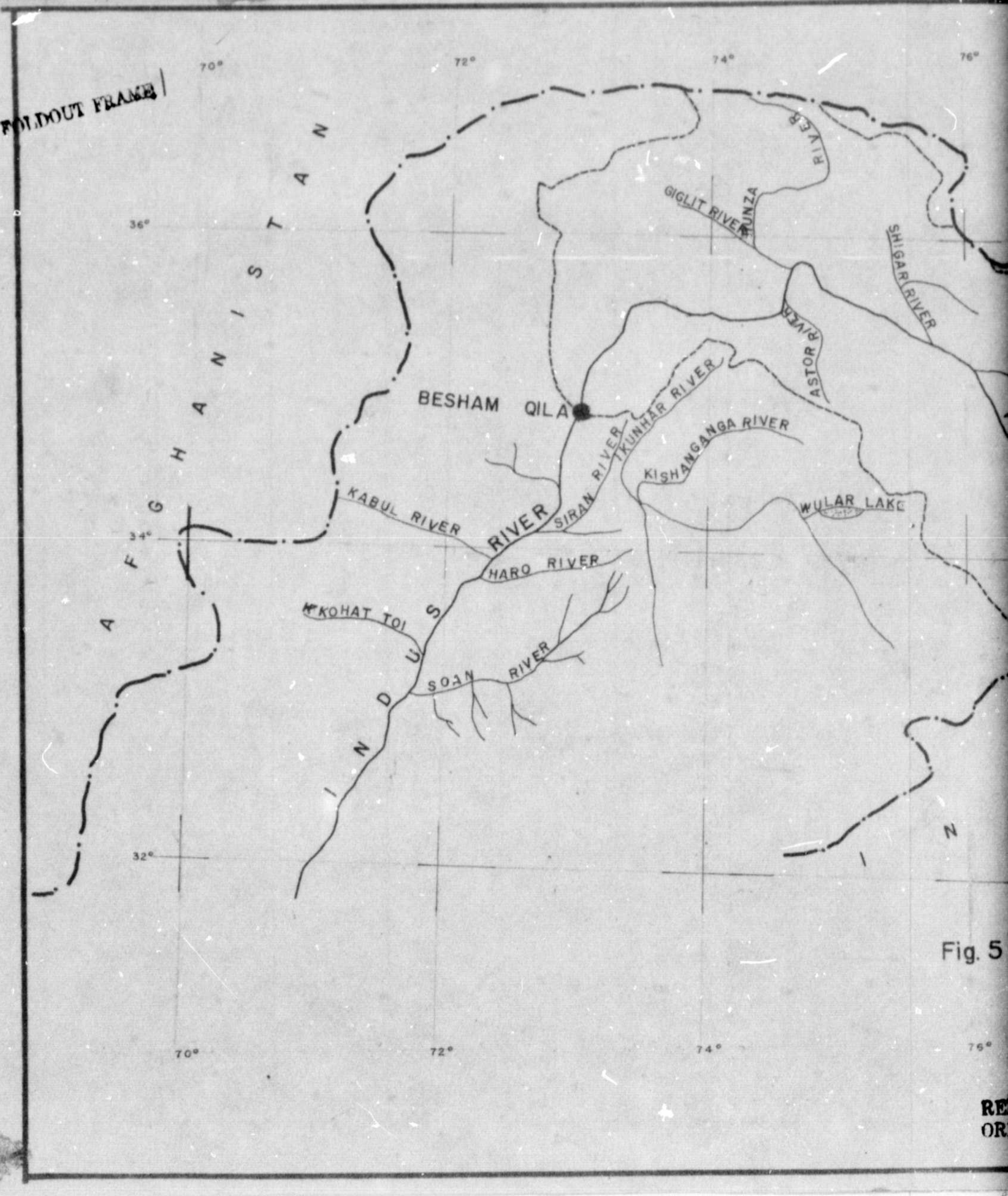



Fig. 4 KUNHAR RIVER AT NARAN

AREA= 400 Sq: Miles



70°
72°
74°
76°
36°
34°
32°
AFGHANISTAN
BESHAM QILA
GIGLIT RIVER
HUNZA RIVER
SHIGAR RIVER
ASTOR RIVER
KUNHAR RIVER
SIRAN RIVER
KISHANGANGA RIVER
WULAR LAKE
KABUL RIVER
INDUS RIVER
HARO RIVER
KOHAT TOI
SOAN RIVER
IN


Fig. 5

RE
OR

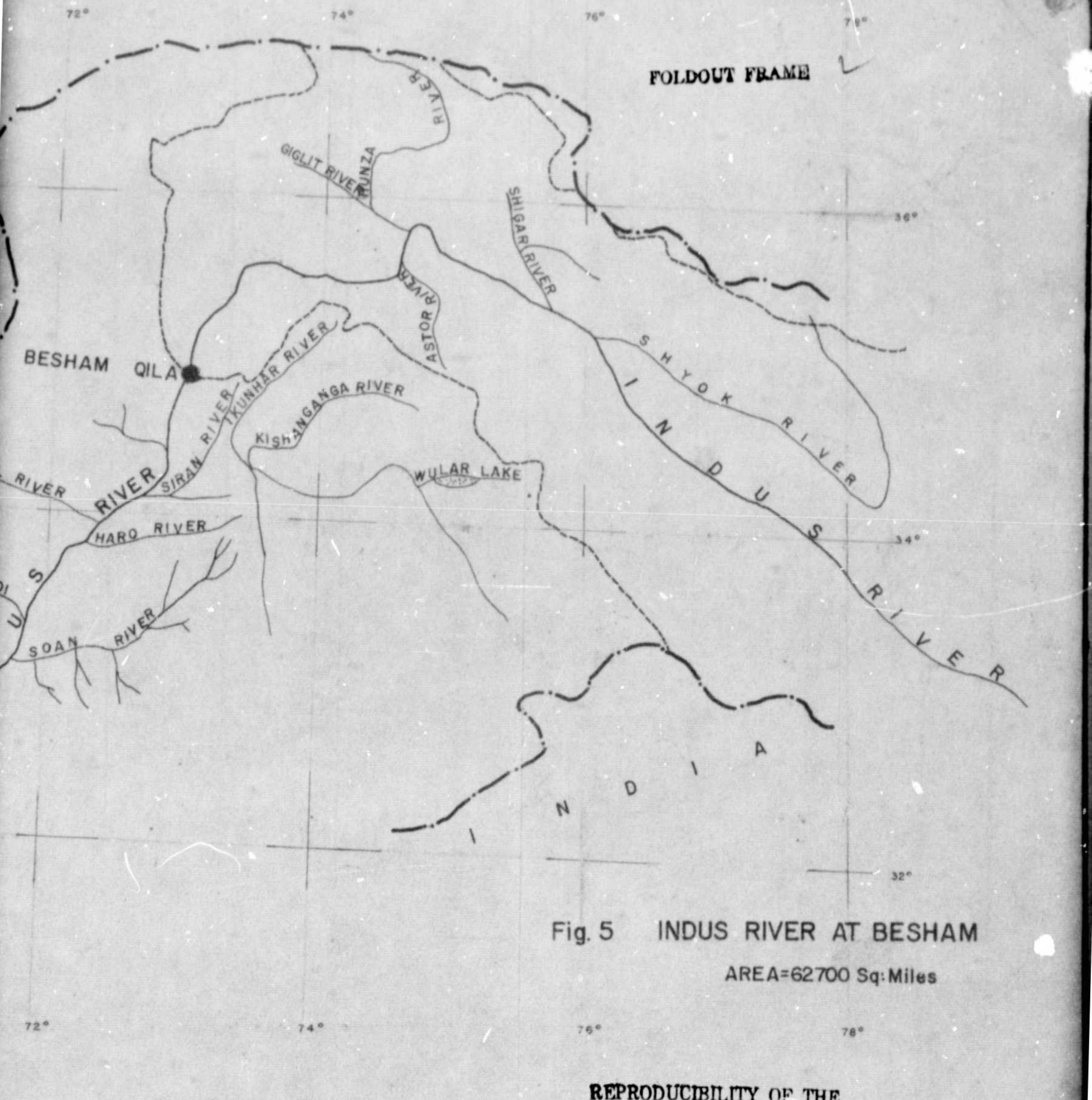



Fig. 5 INDUS RIVER AT BESHAM

AREA=62700 Sq: Miles

FOLDOUT FRAME

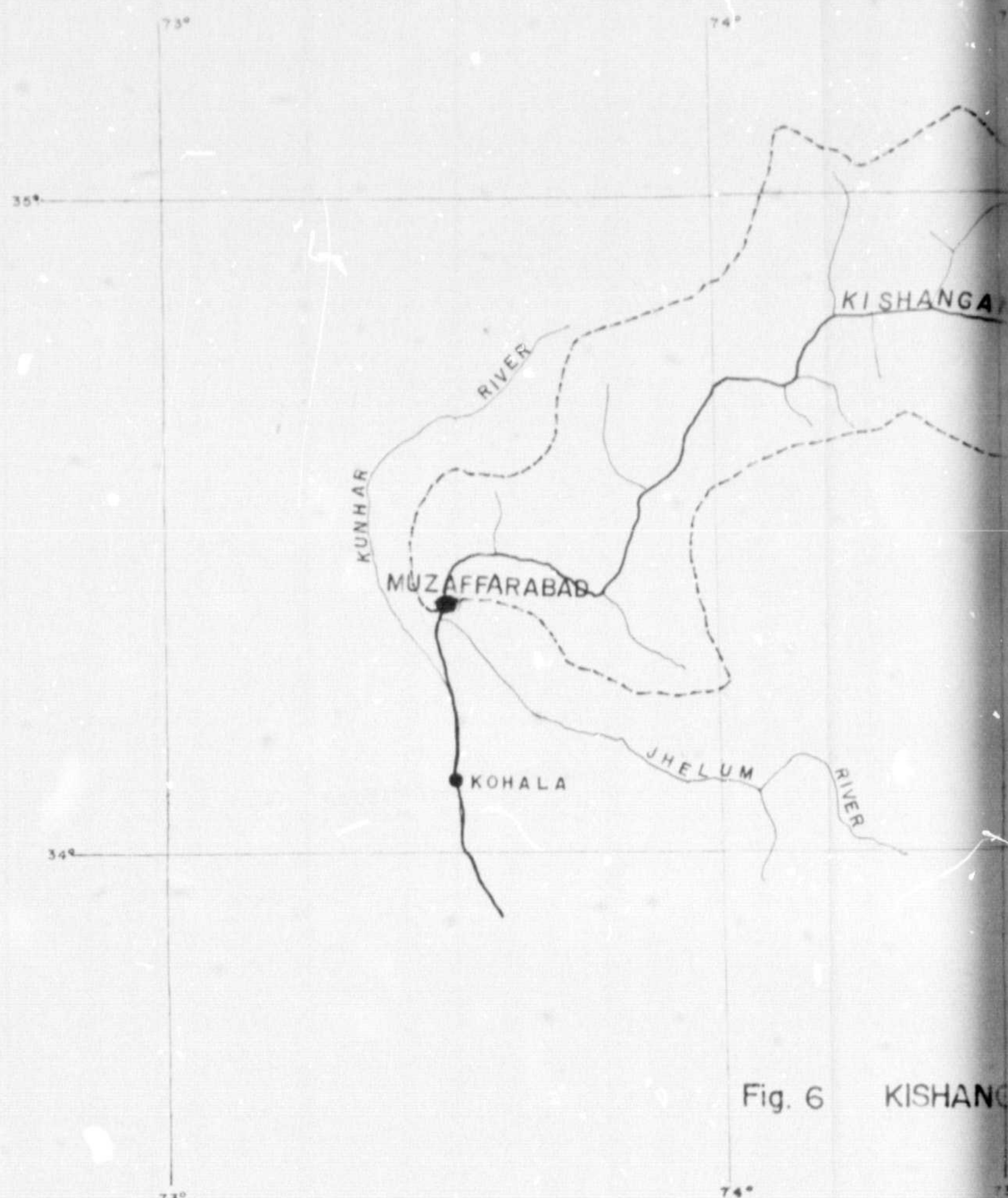



Fig. 6 KISHANG

FOLDOUT FRAME 2

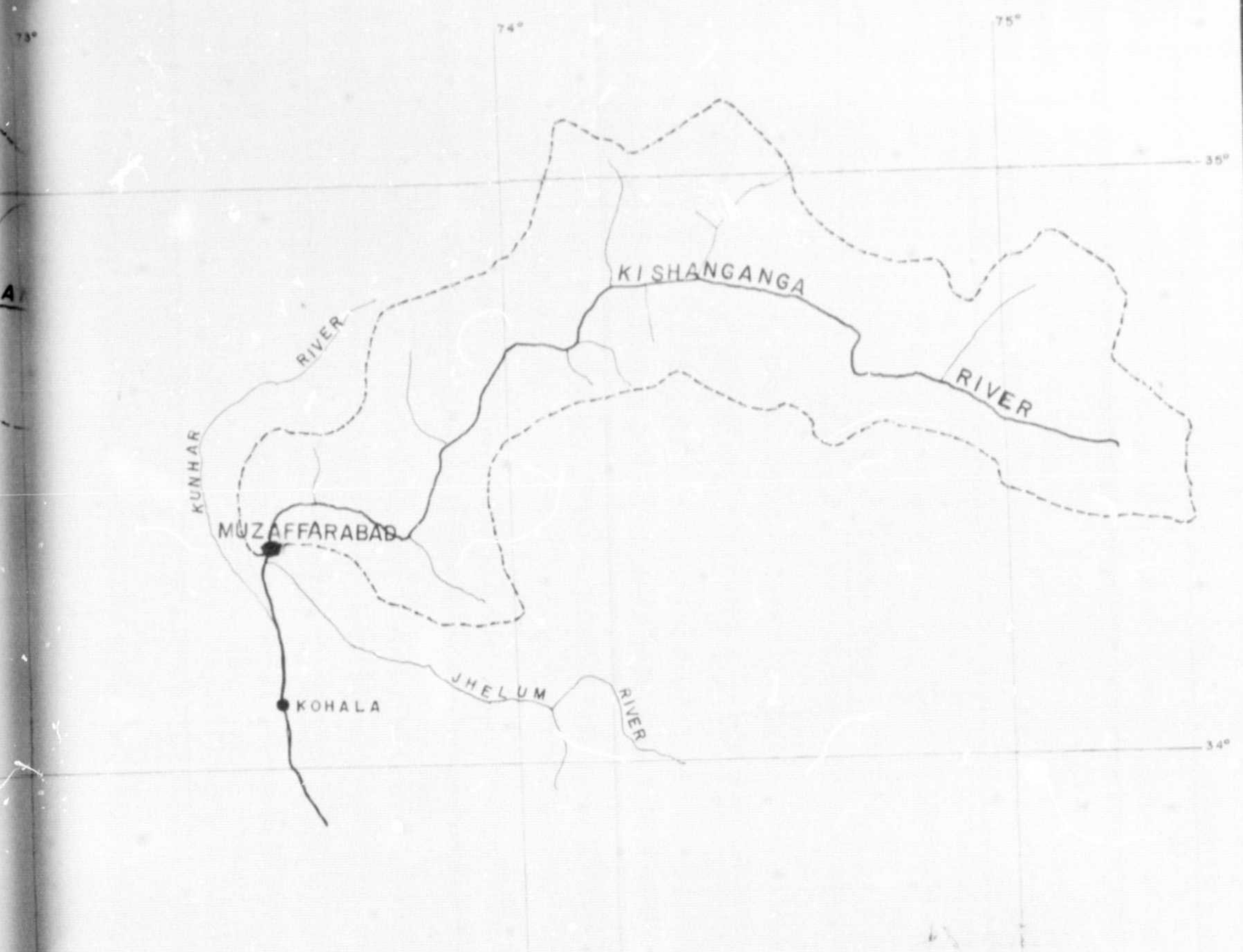
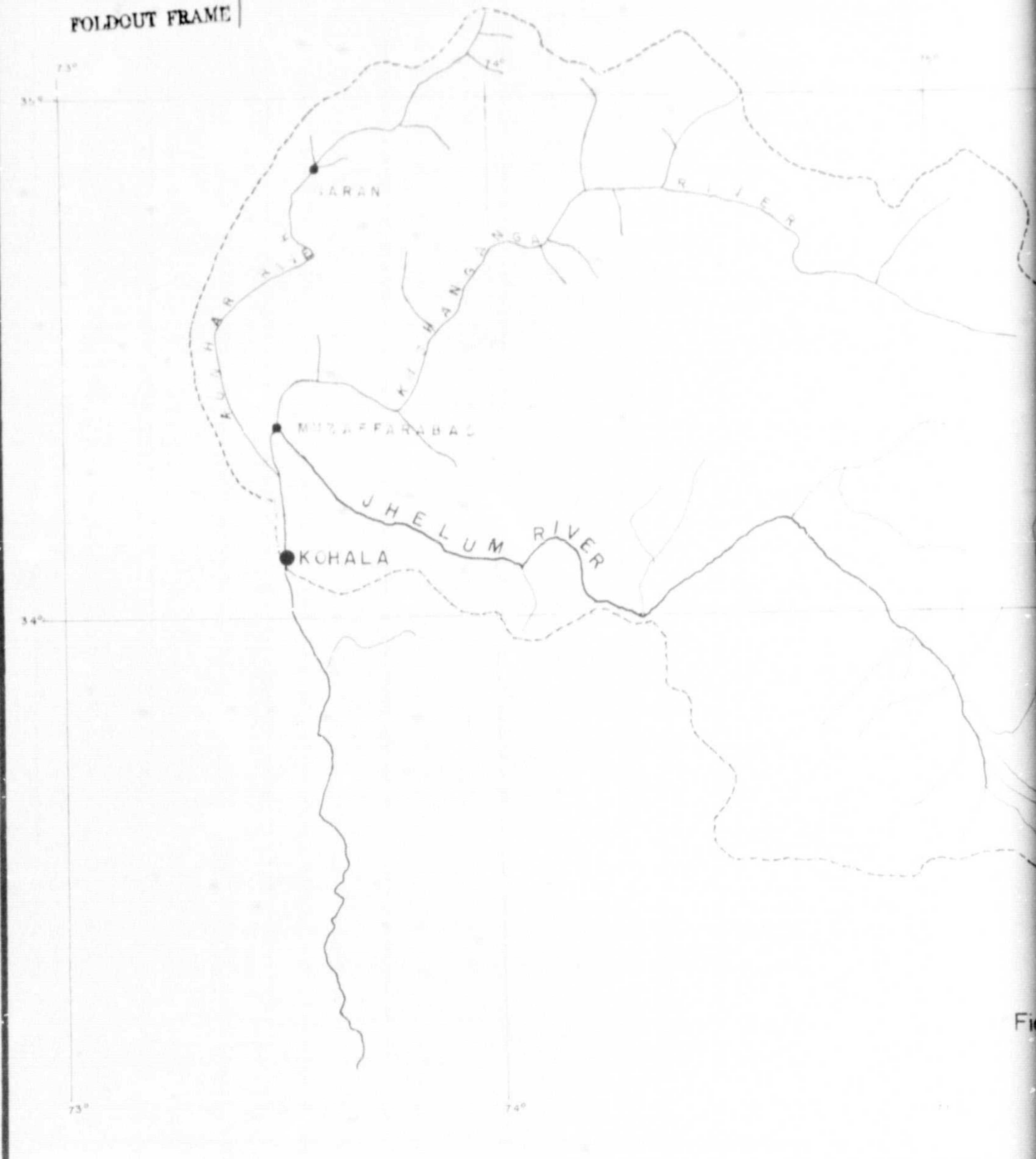



Fig. 6 KISHANGANGA RIVER AT MUZAFFARABAD

AREA= 2810 Sq. Miles

FOLDOUT FRAME



FOLDOUT FRAME 2

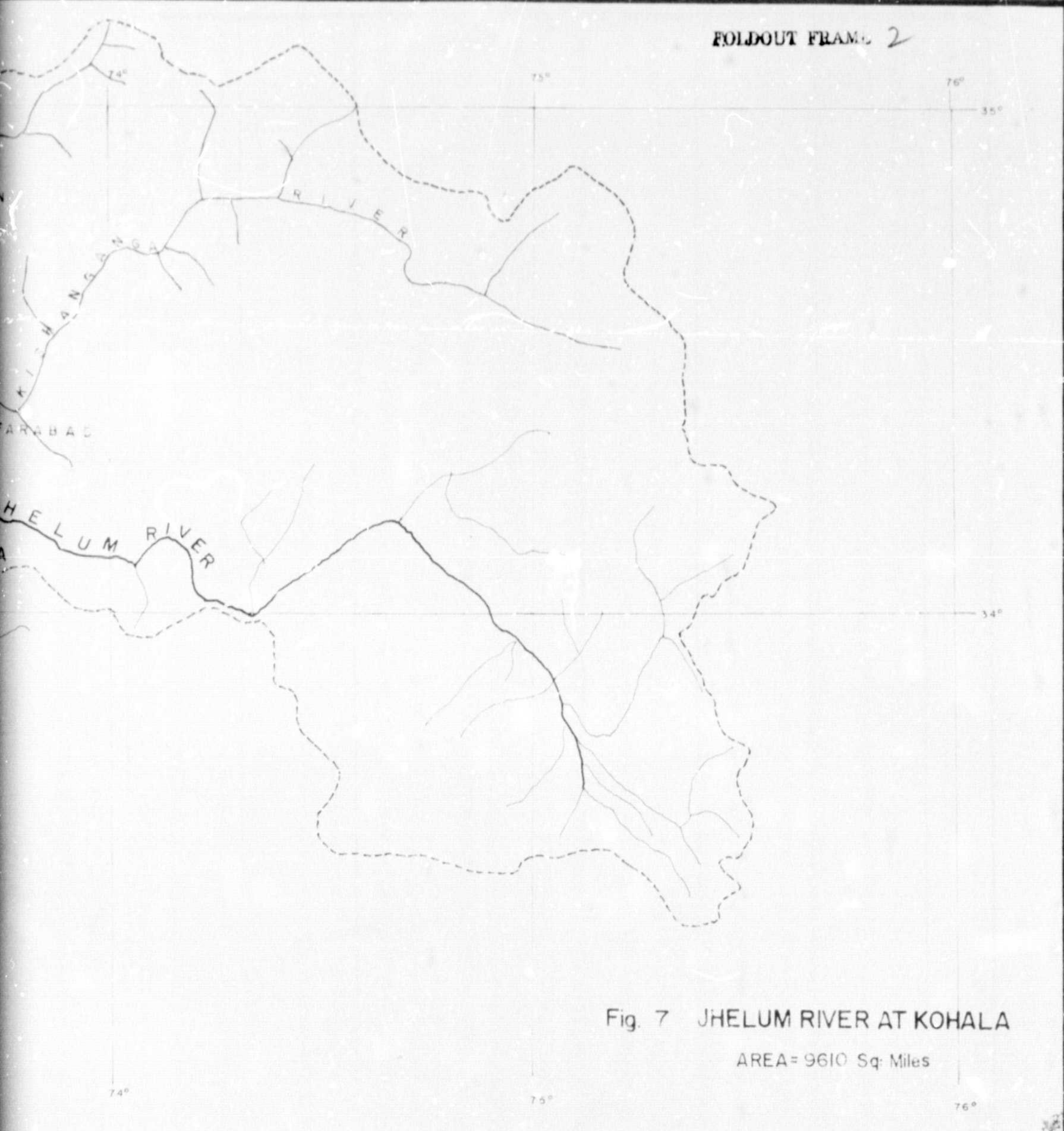



Fig. 7 JHELUM RIVER AT KOHALA

AREA= 9610 Sq: Miles

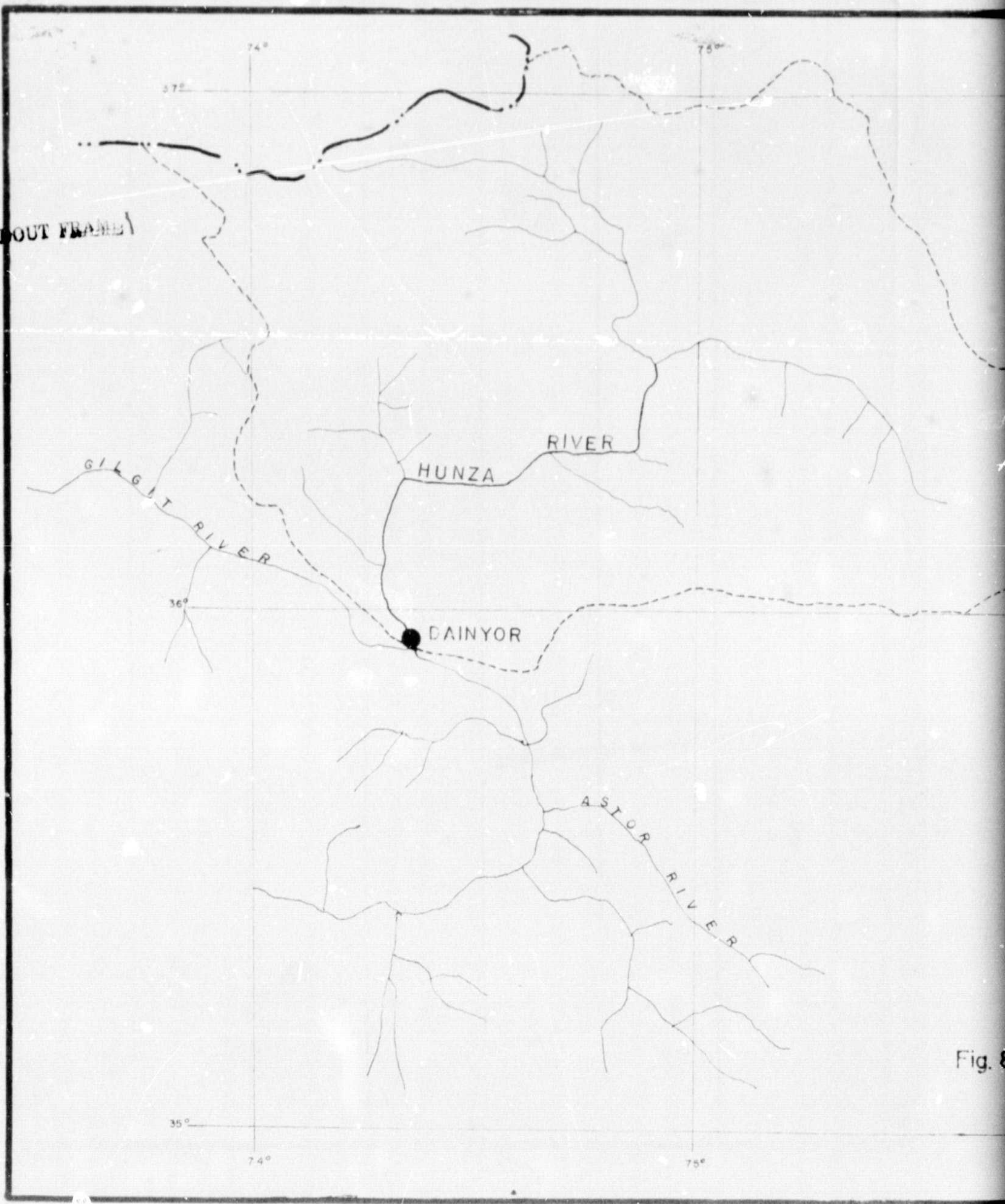

74°
75°
37°
HUNZA
RIVER
GILGIT RIVER
36°
DAINYOR
ASTOR RIVER
35°
74°
75°

Fig. 8

FOLDOUT FRAME 2

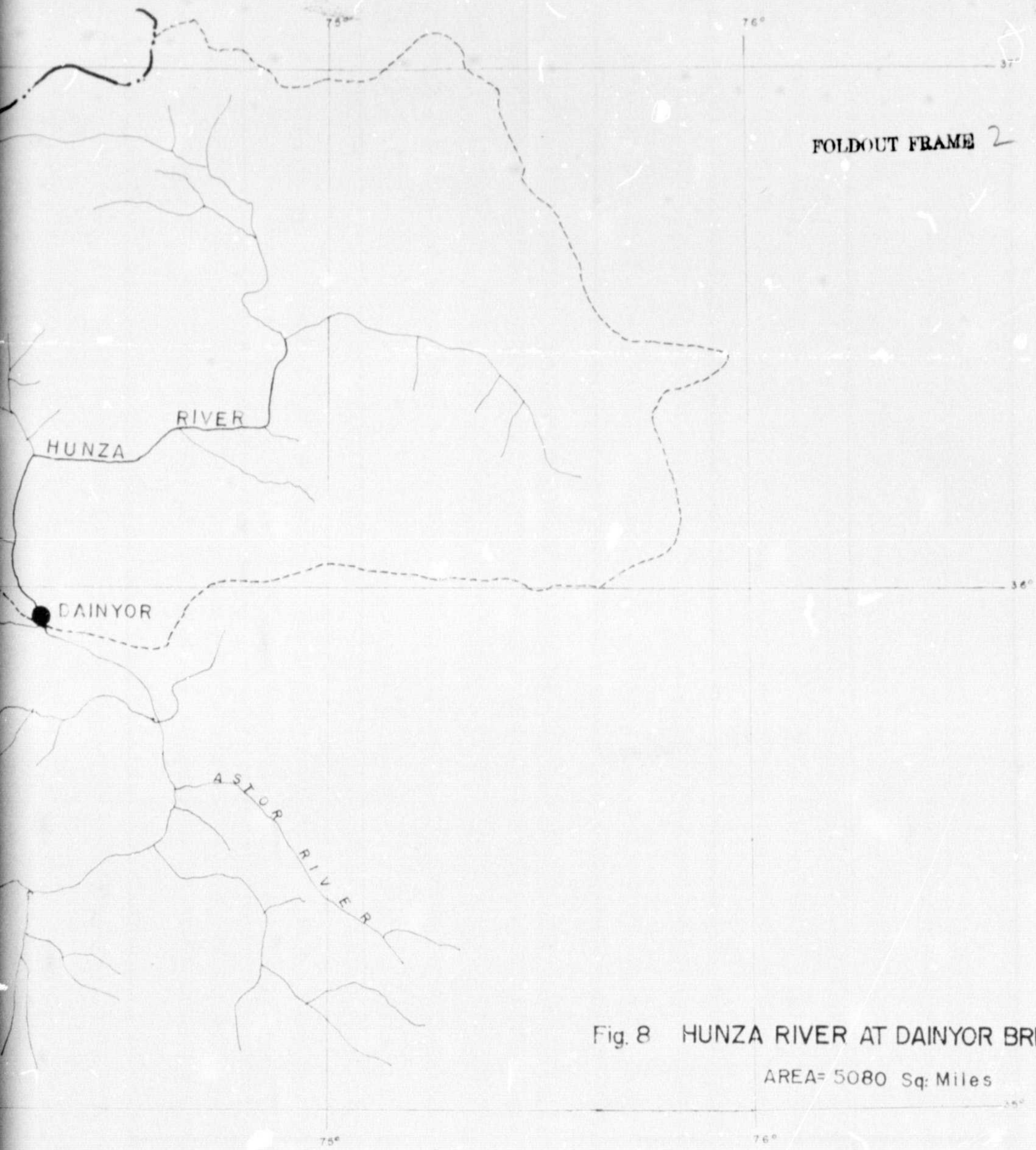



Fig. 8 HUNZA RIVER AT DAINYOR BRIDGE

AREA= 5080 Sq: Miles

FOLDOUT FRAME

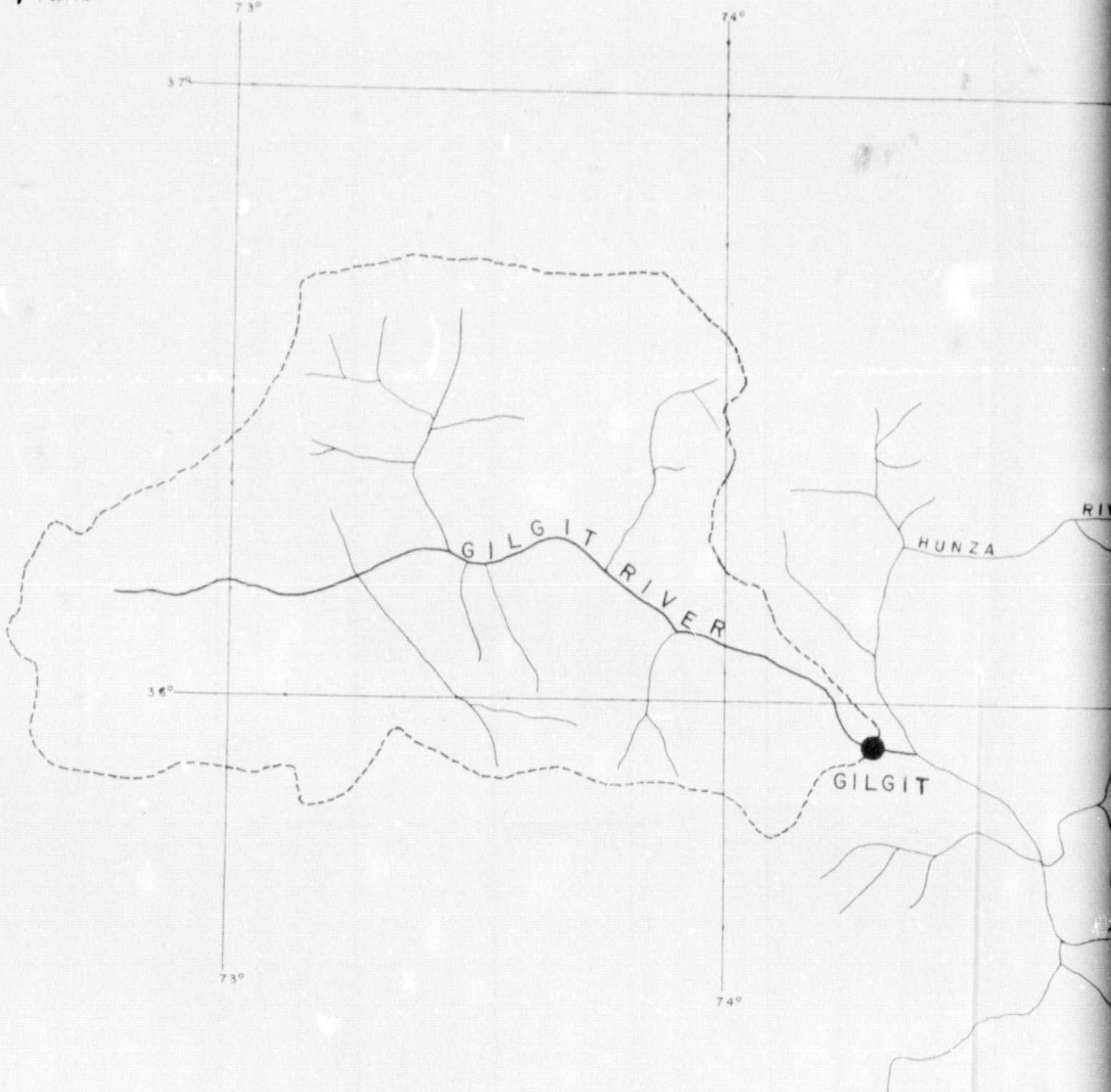



Fig. 9 G

FOLDOUT FRAME 2

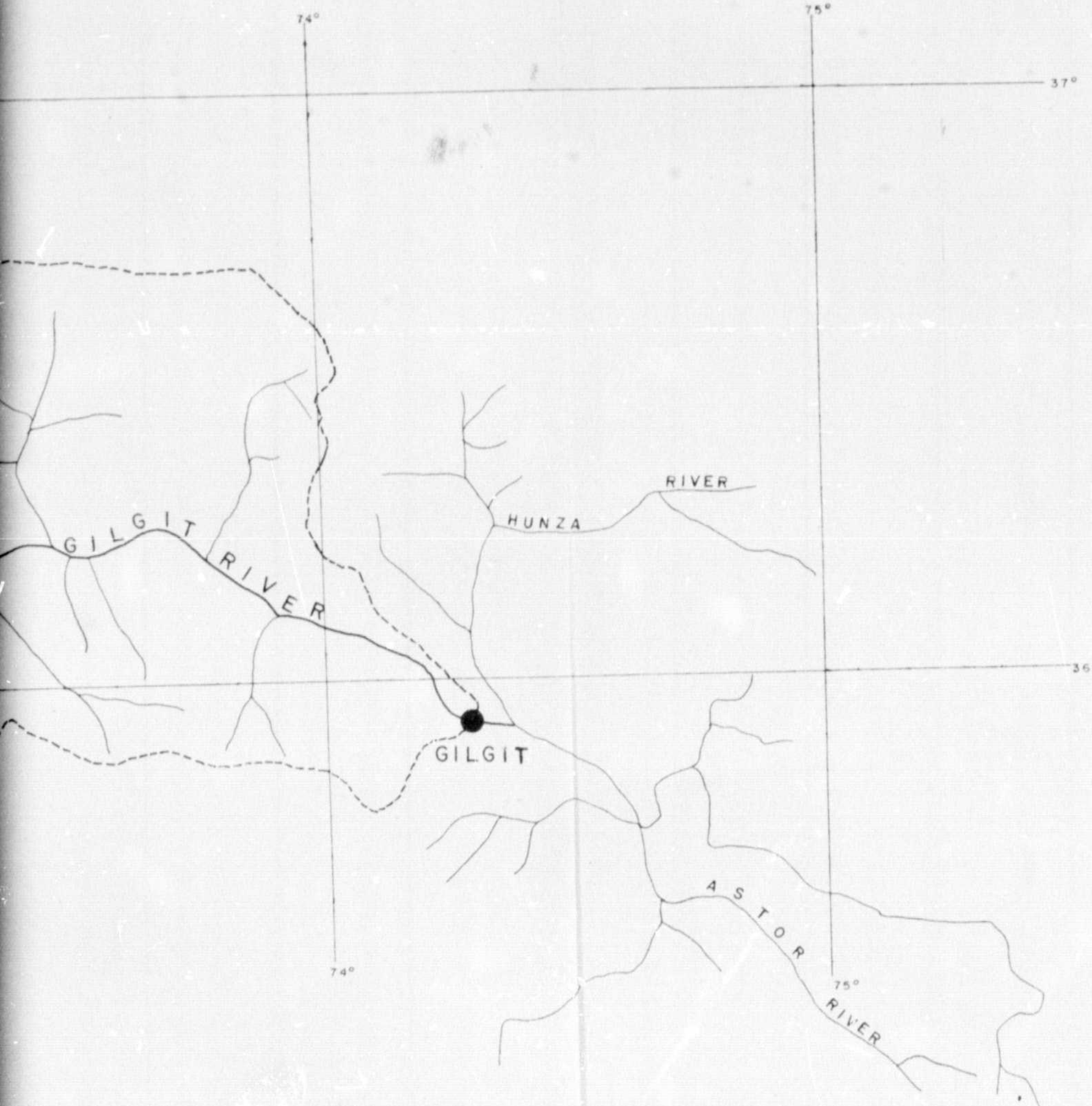
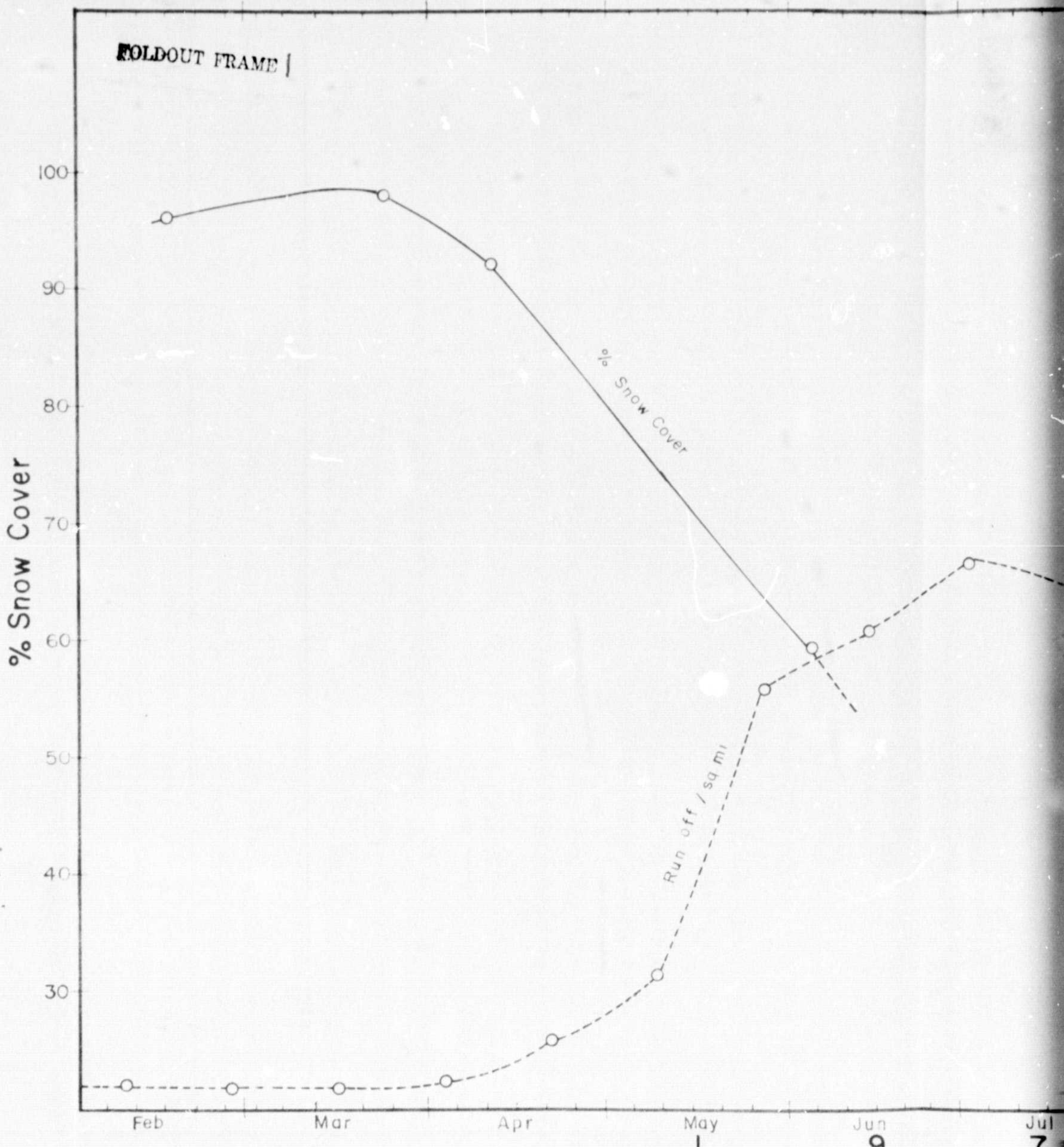



Fig. 9 GILGIT RIVER AT GILGIT

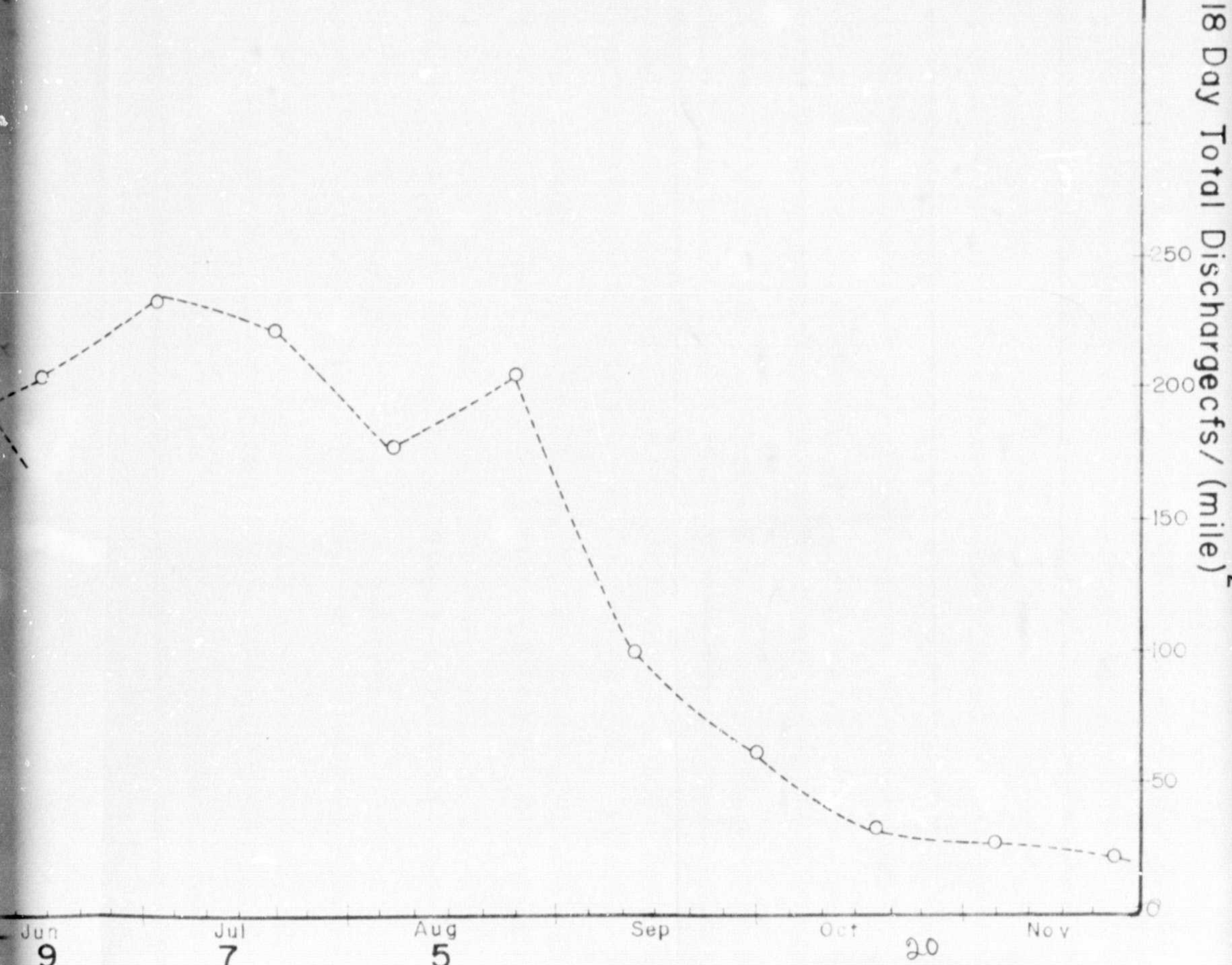
AREA= 4670 Sq. Miles


FOLDOUT FRAME 1
% Snow Cover
100
90
80
70
60
50
40
30
% Snow Cover
Run off / sq mi
Feb
Mar
Apr
May
Jun
Jul
1
9
7

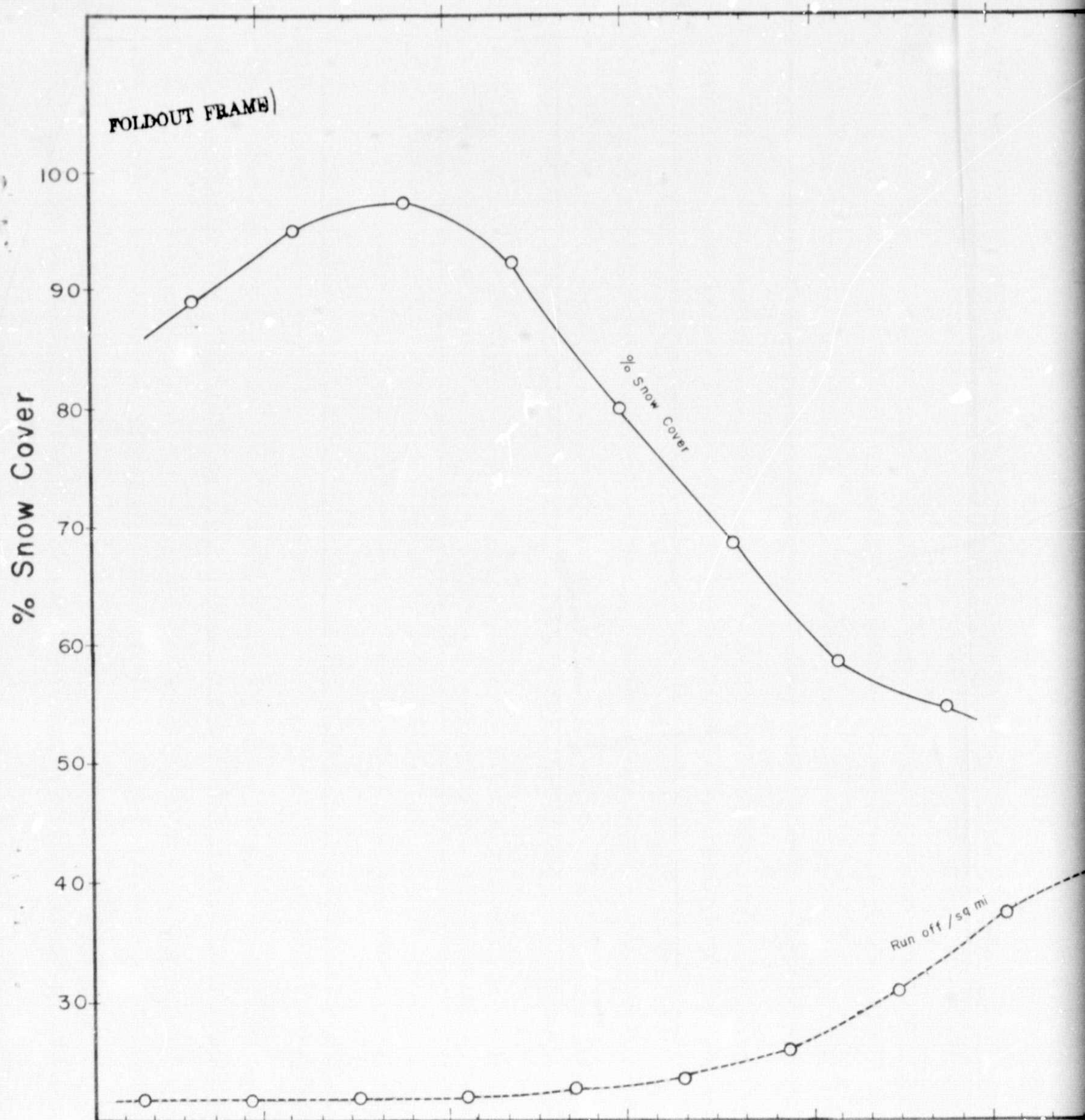
FOLDOUT FRAME 2

Fig- 10

# SWAT RIVER NEAR KALAM 1975.



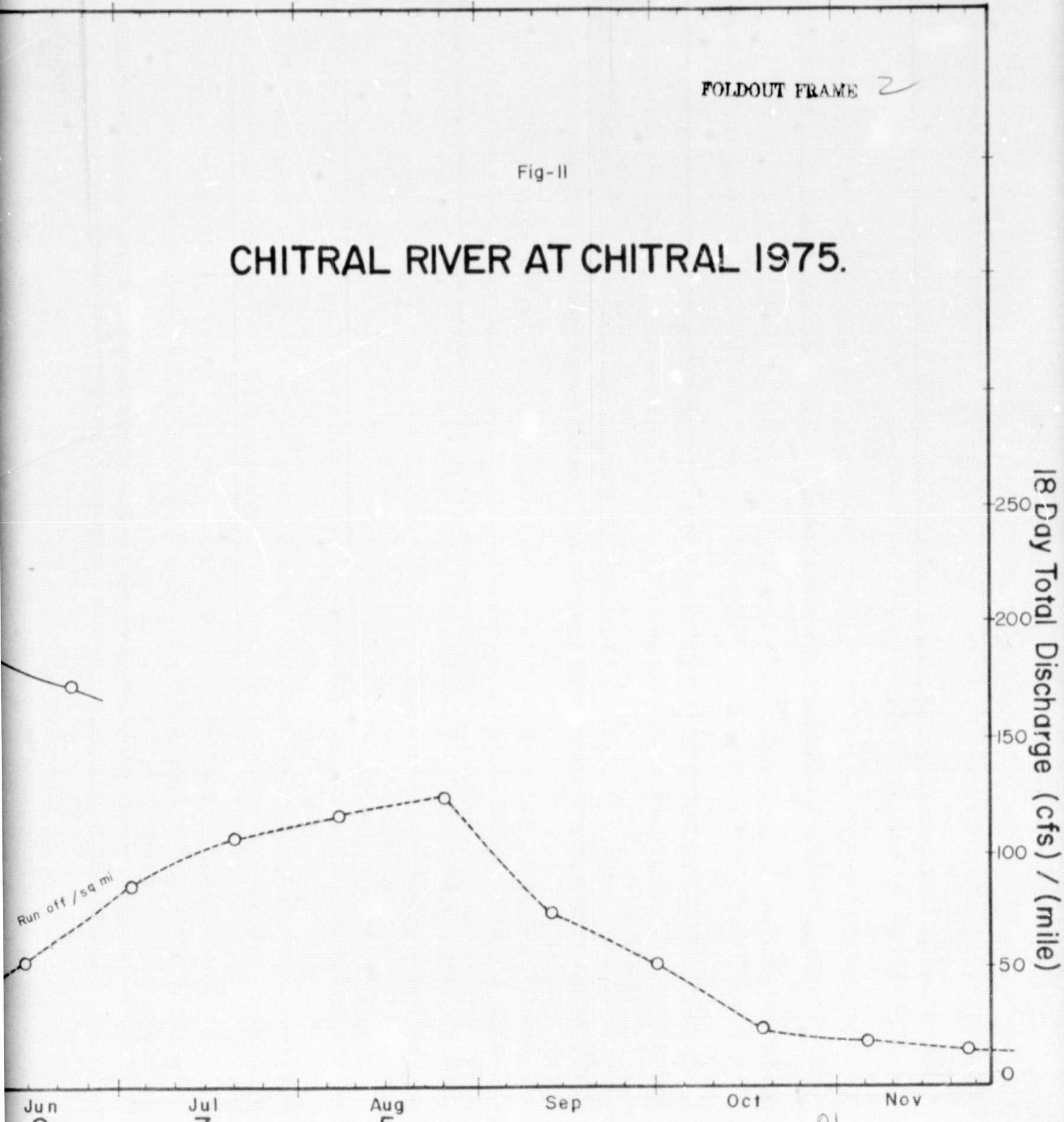
FOLDOUT FRAME



FOLDOUT FRAME 2

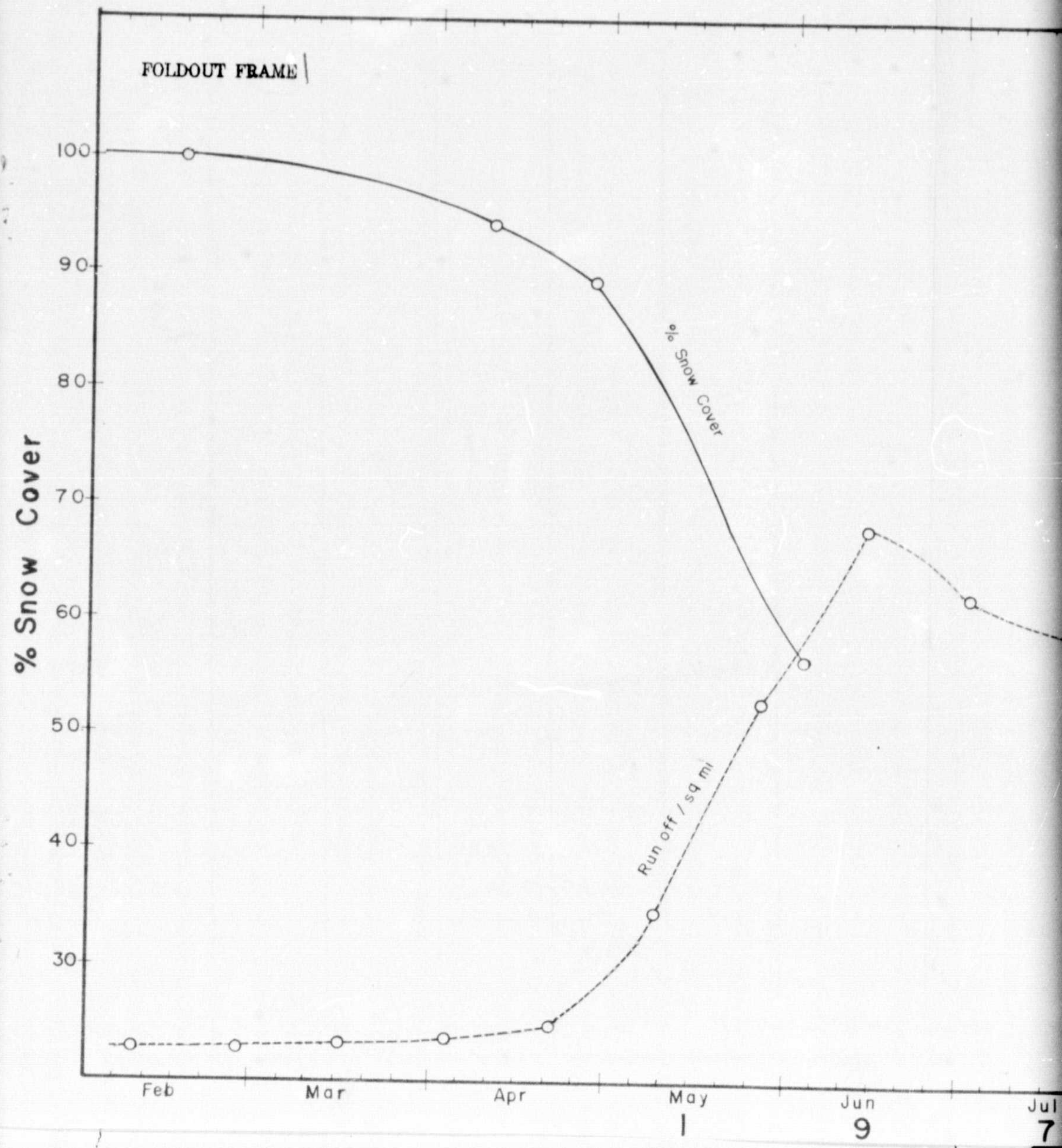
Fig-II

# CHITRAL RIVER AT CHITRAL 1975.




21

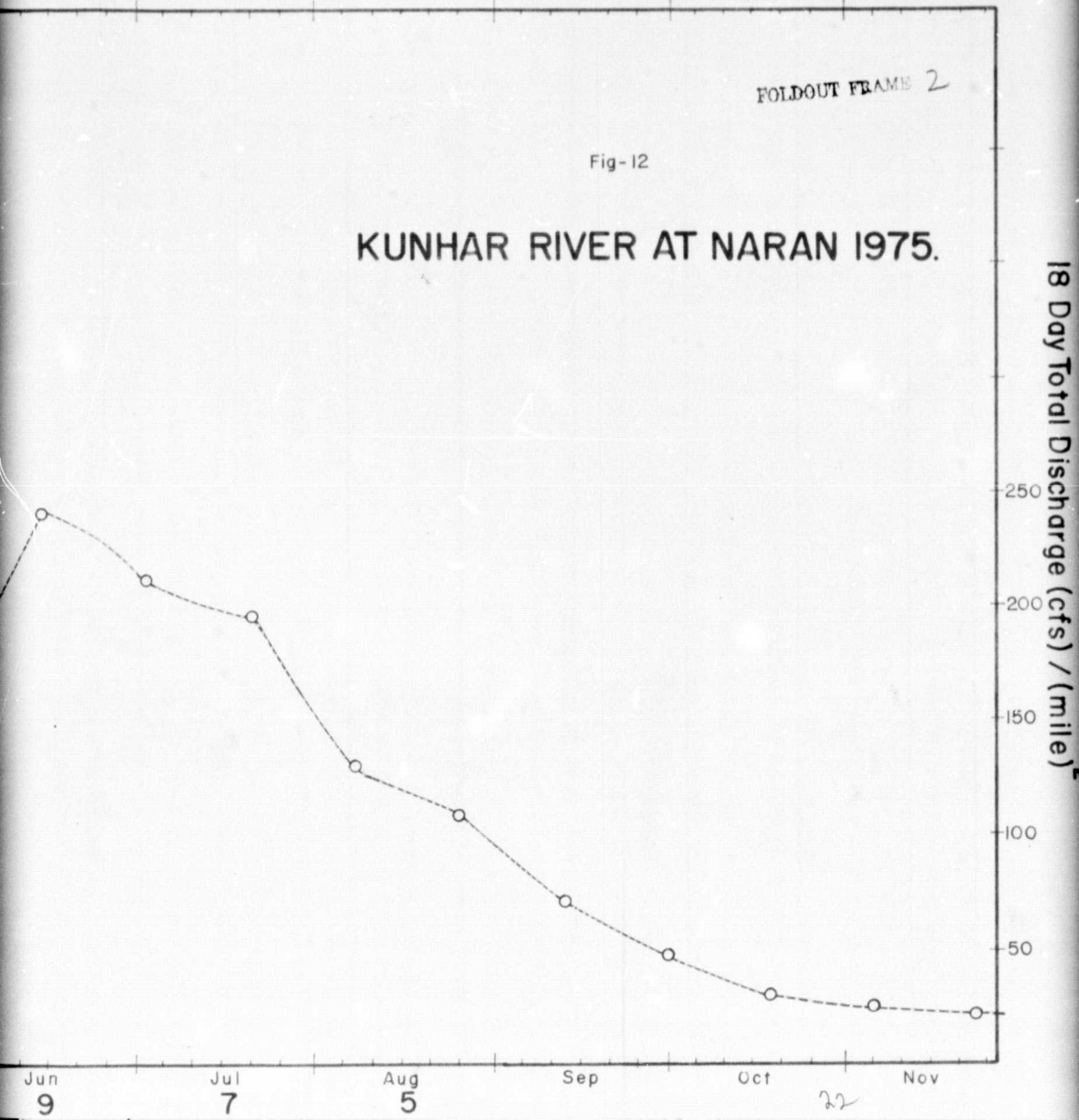
FOLDOUT FRAME



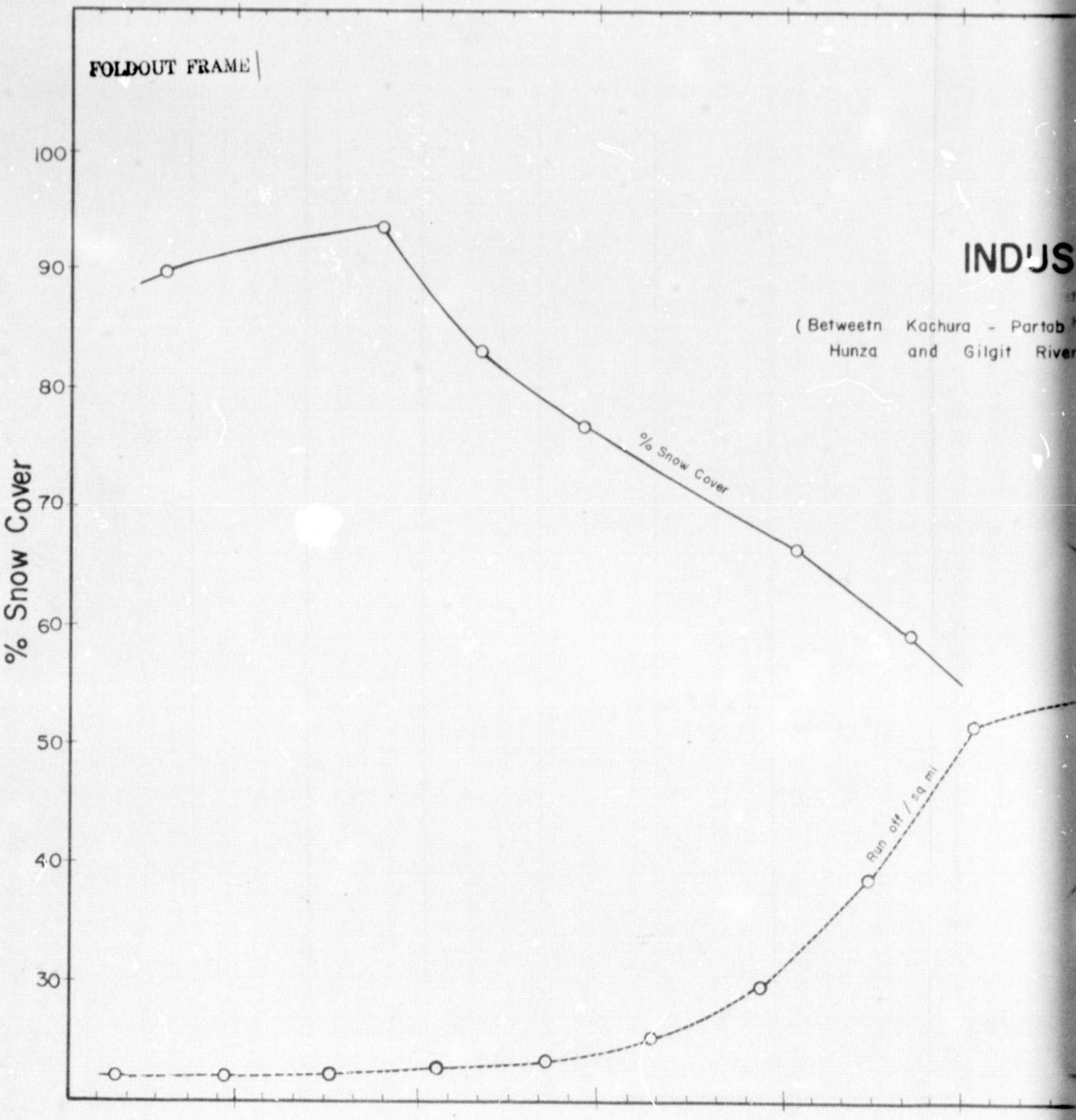
FOLDOUT FRAME 2

Fig-12

KUNHAR RIVER AT NARAN 1975.



FOLDOUT FRAME 1

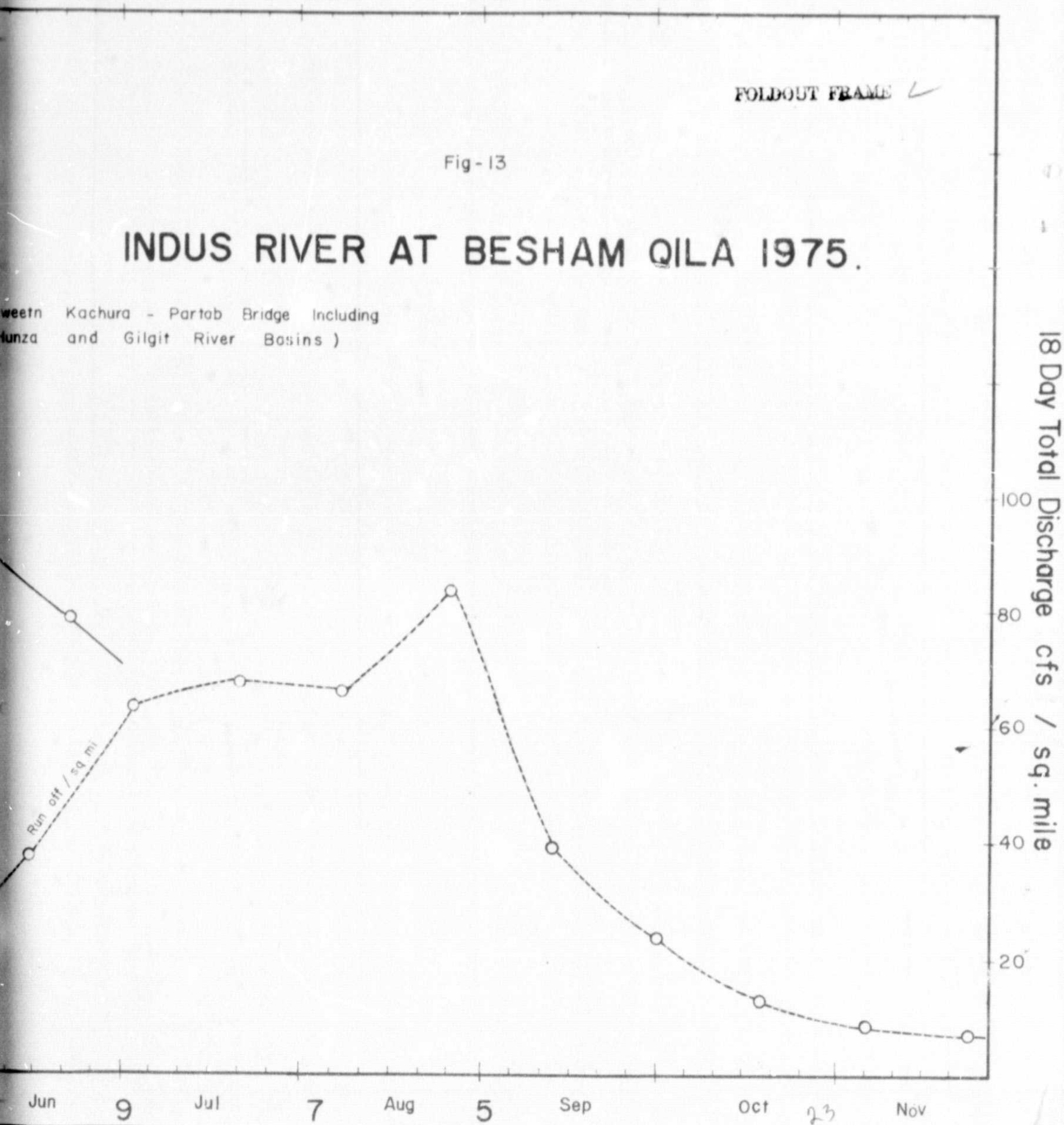


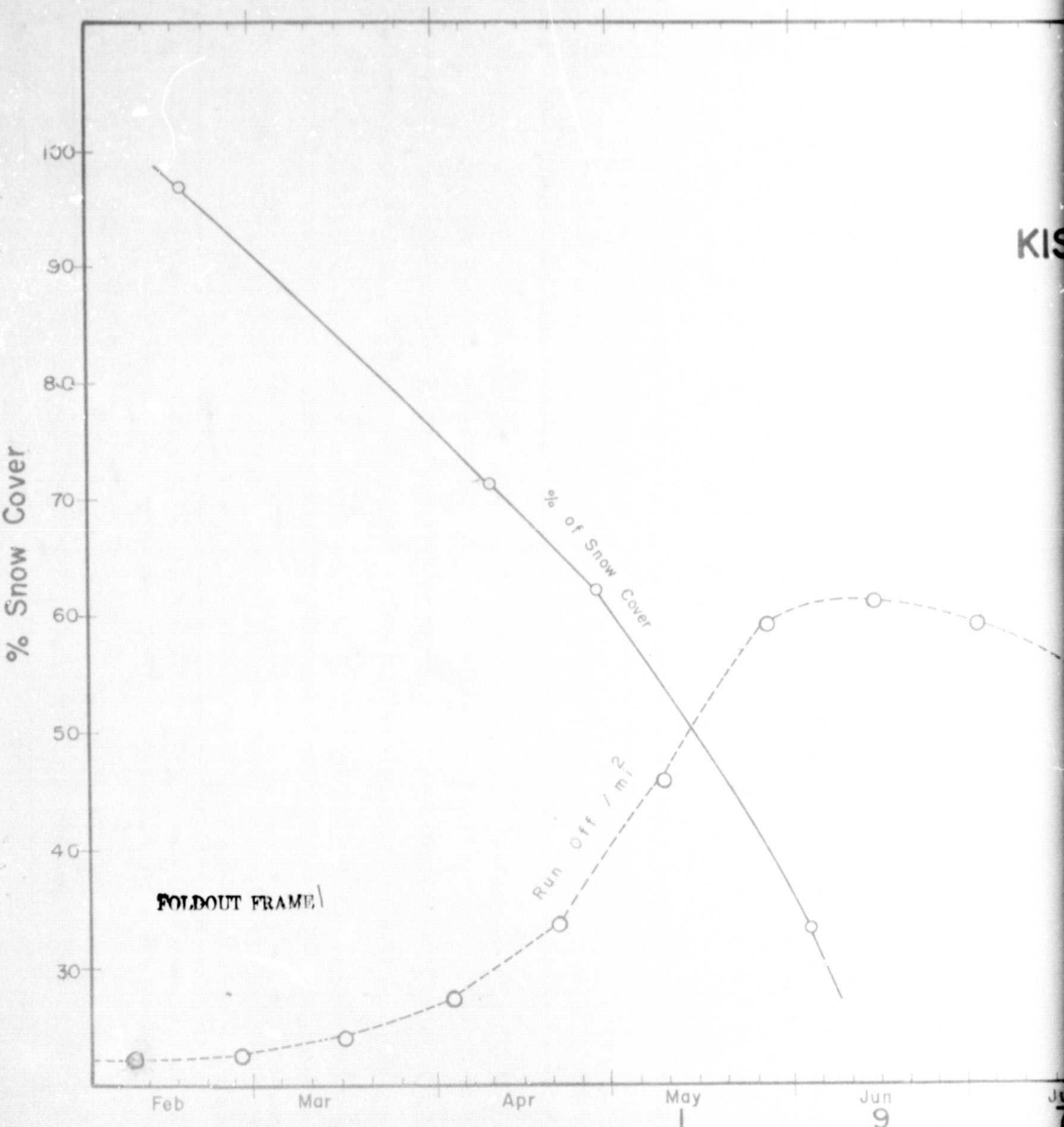
FOLDOUT FRAME

Fig - 13

# INDUS RIVER AT BESHAM QILA 1975.

weetn Kachura - Partab Bridge Including
lunza and Gilgit River Basins )





KIS
% Snow Cover
100
90
80
70
60
50
40
30
% of Snow Cover
Run Off / mi2
FOLDOUT FRAME
Feb
Mar
Apr
May
Jun
1
9

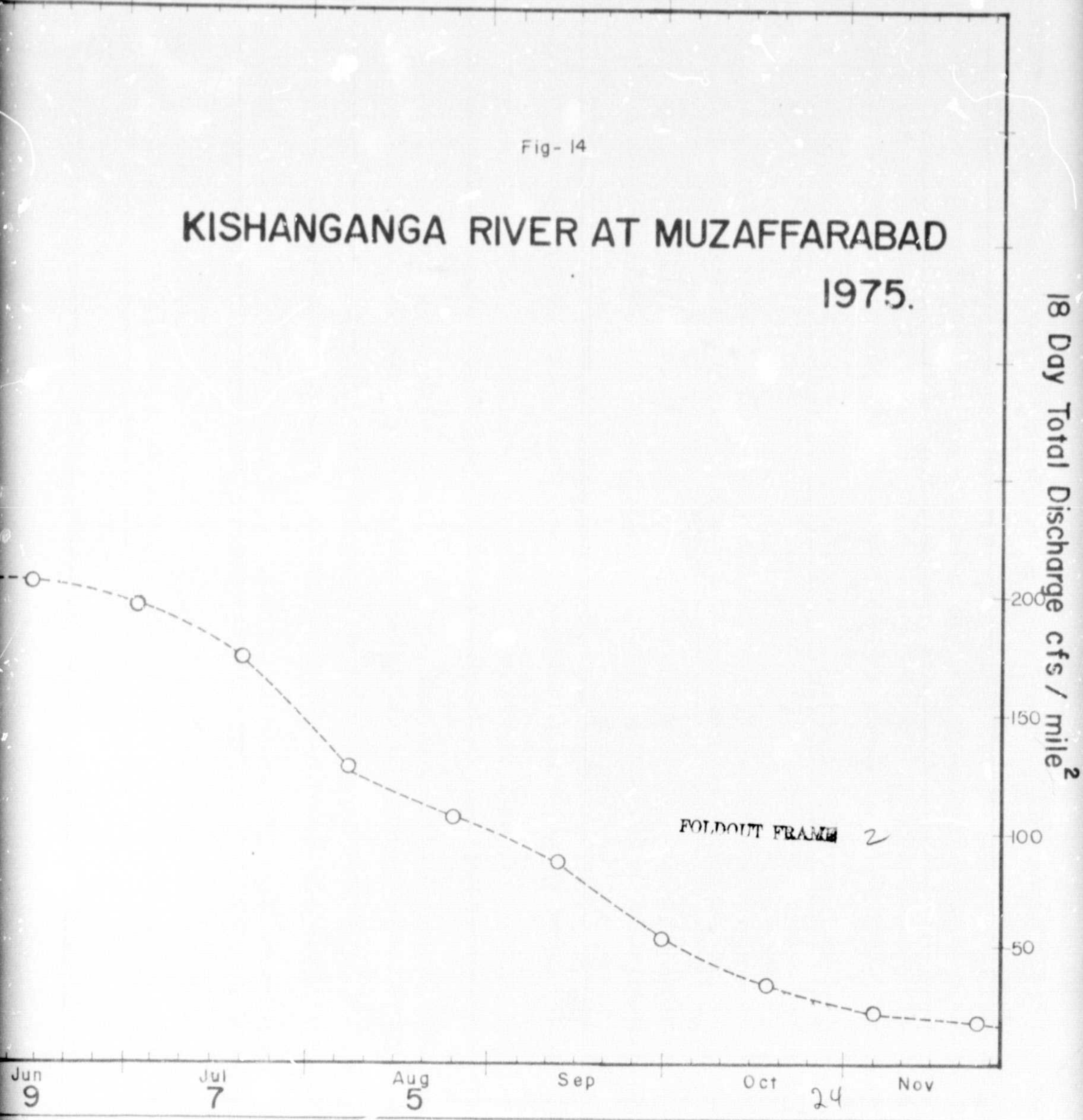
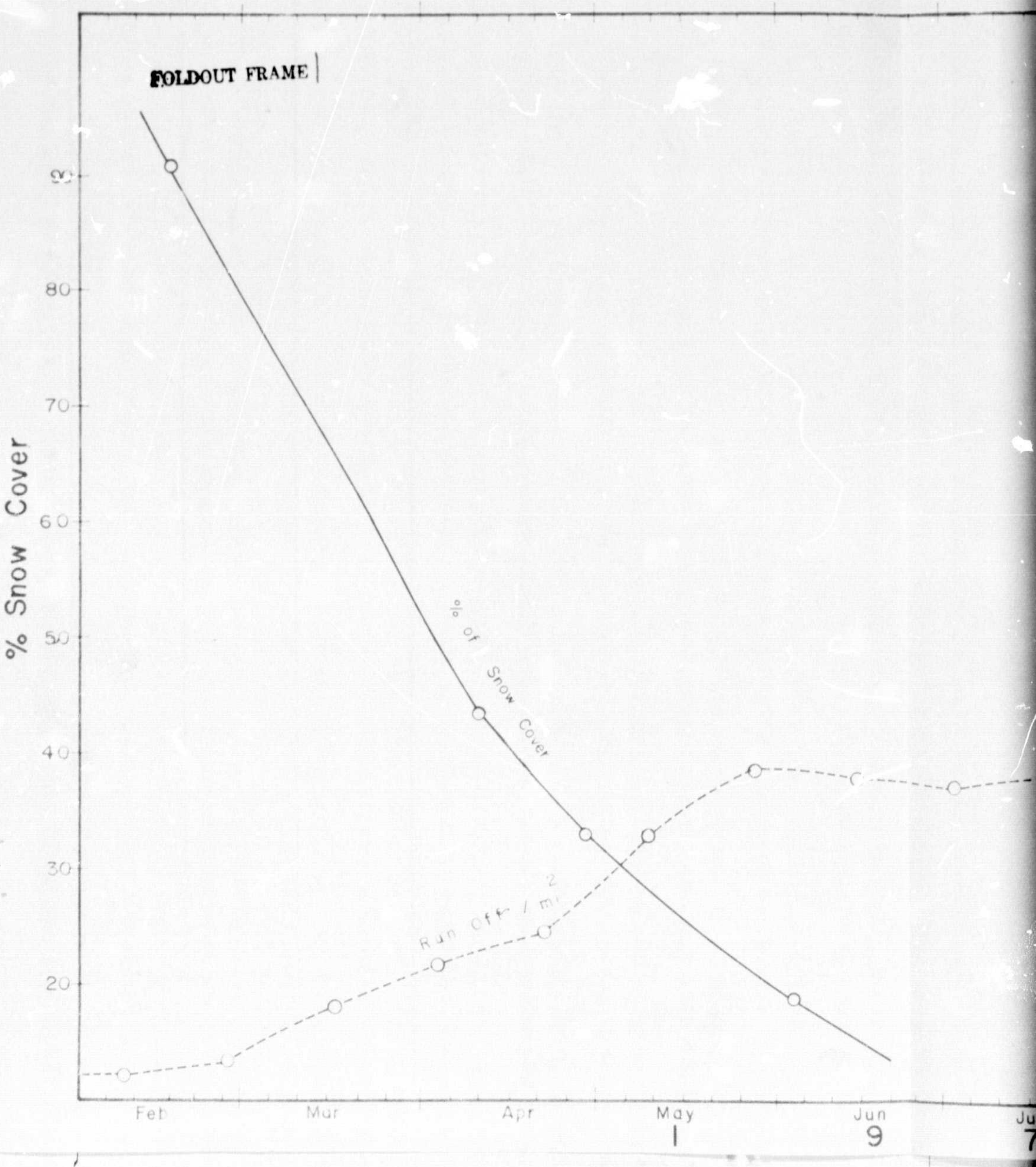
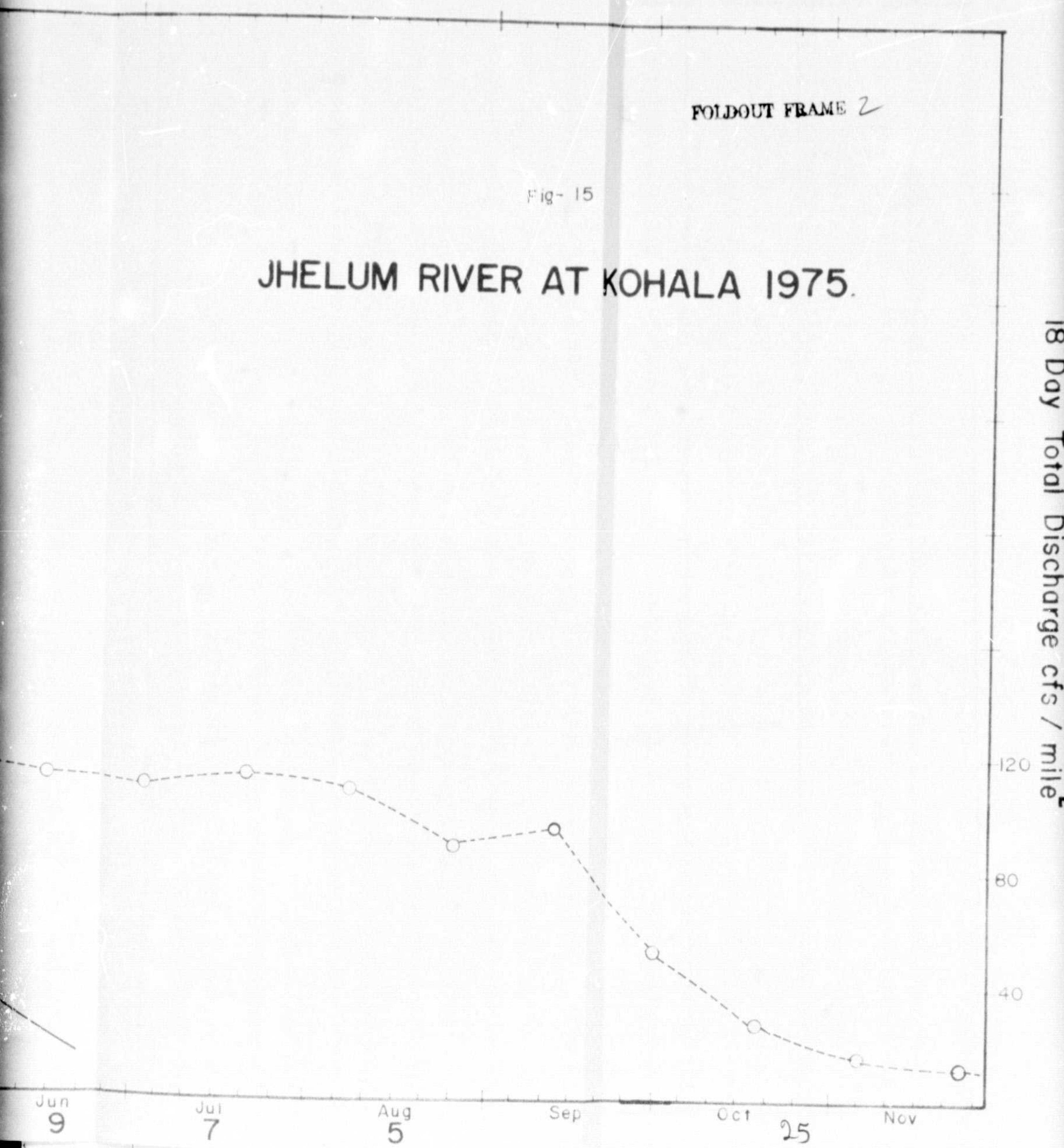


Fig- 14
KISHANGANGA RIVER AT MUZAFFARABAD
1975.
18 Day Total Discharge cfs / mile²
200
150
100
50
Jun
9
Jul
7
Aug
5
Sep
Oct
24
Nov
FOLDOUT FRAME 2

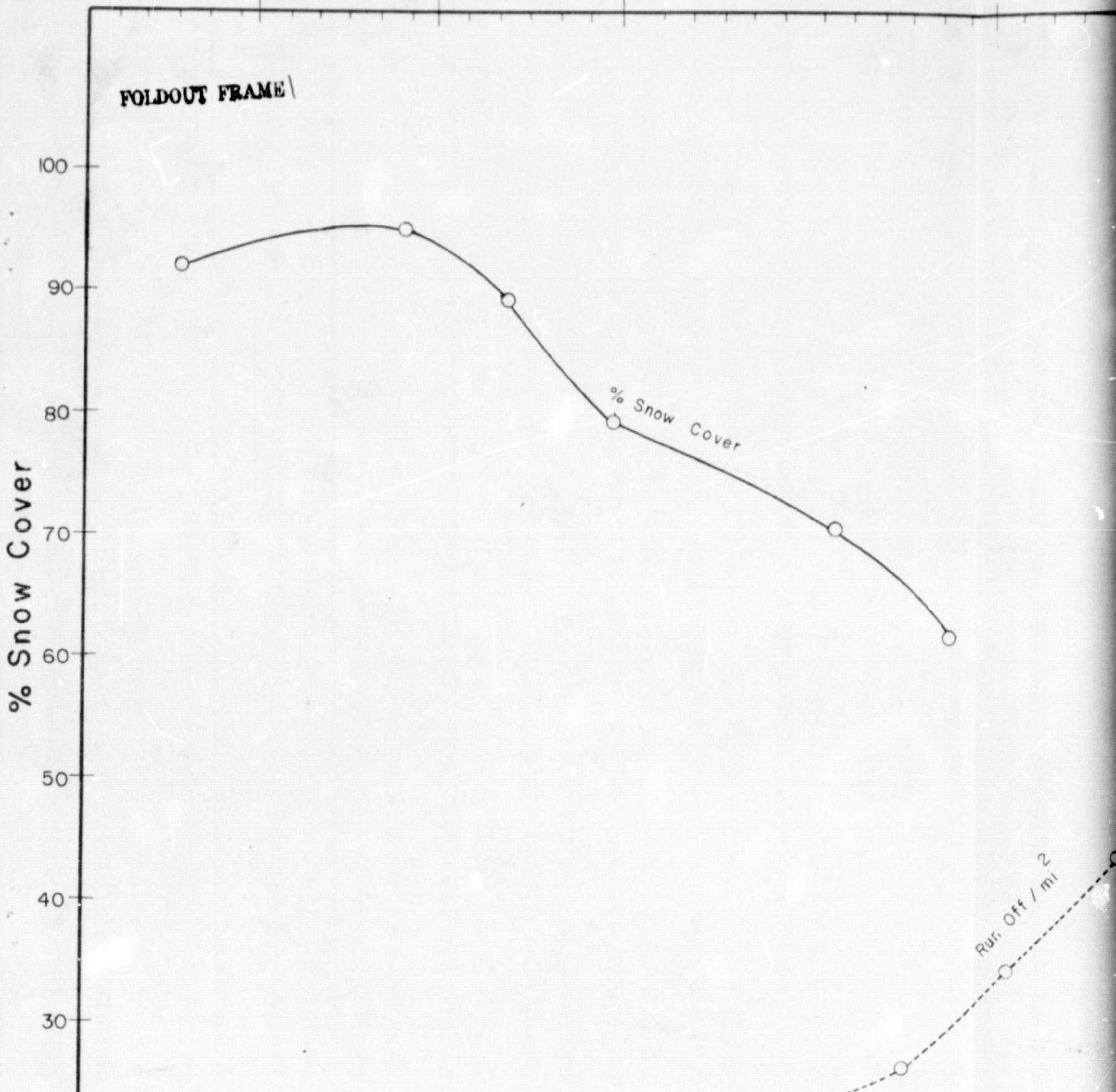

% Snow Cover
90
80
70
60
50
40
30
20
% of Snow Cover
Run Off / mi 2
Feb
Mar
Apr
May
Jun
Ju
1
9
7

FOLDOUT FRAME 2

Fig- 15

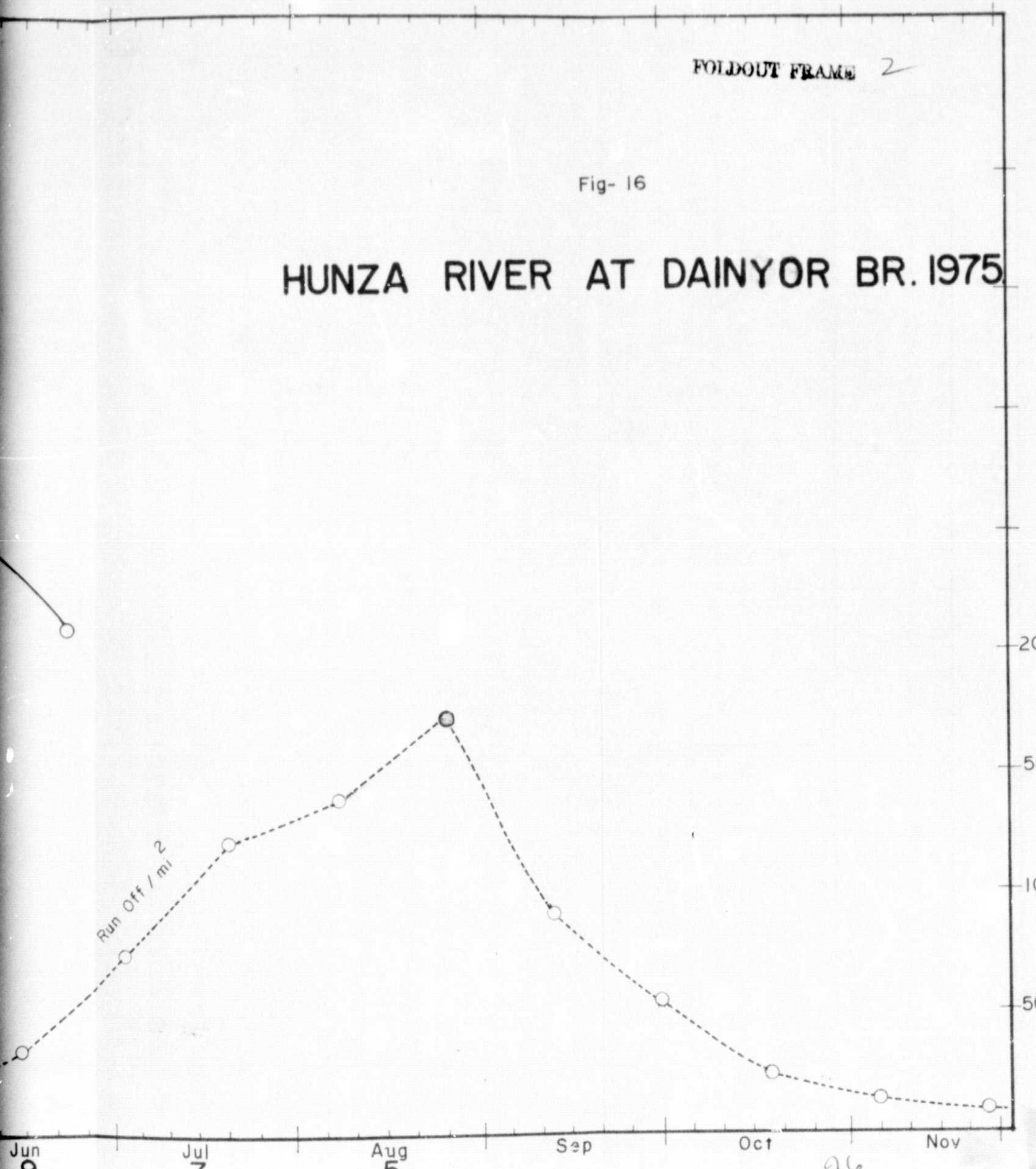


FOLDOUT FRAME



FOLDOUT FRAME 2

Fig- 16




96

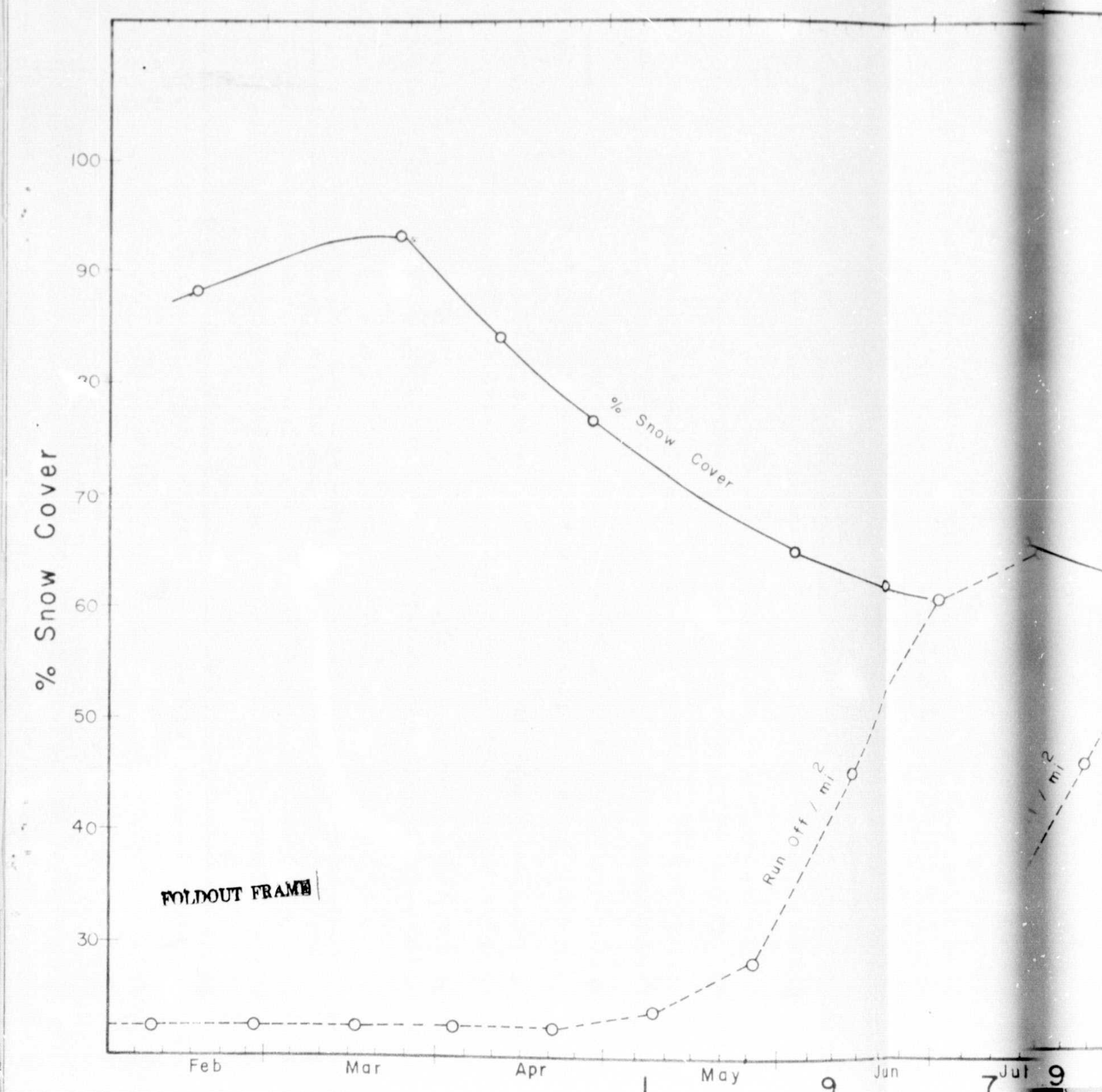
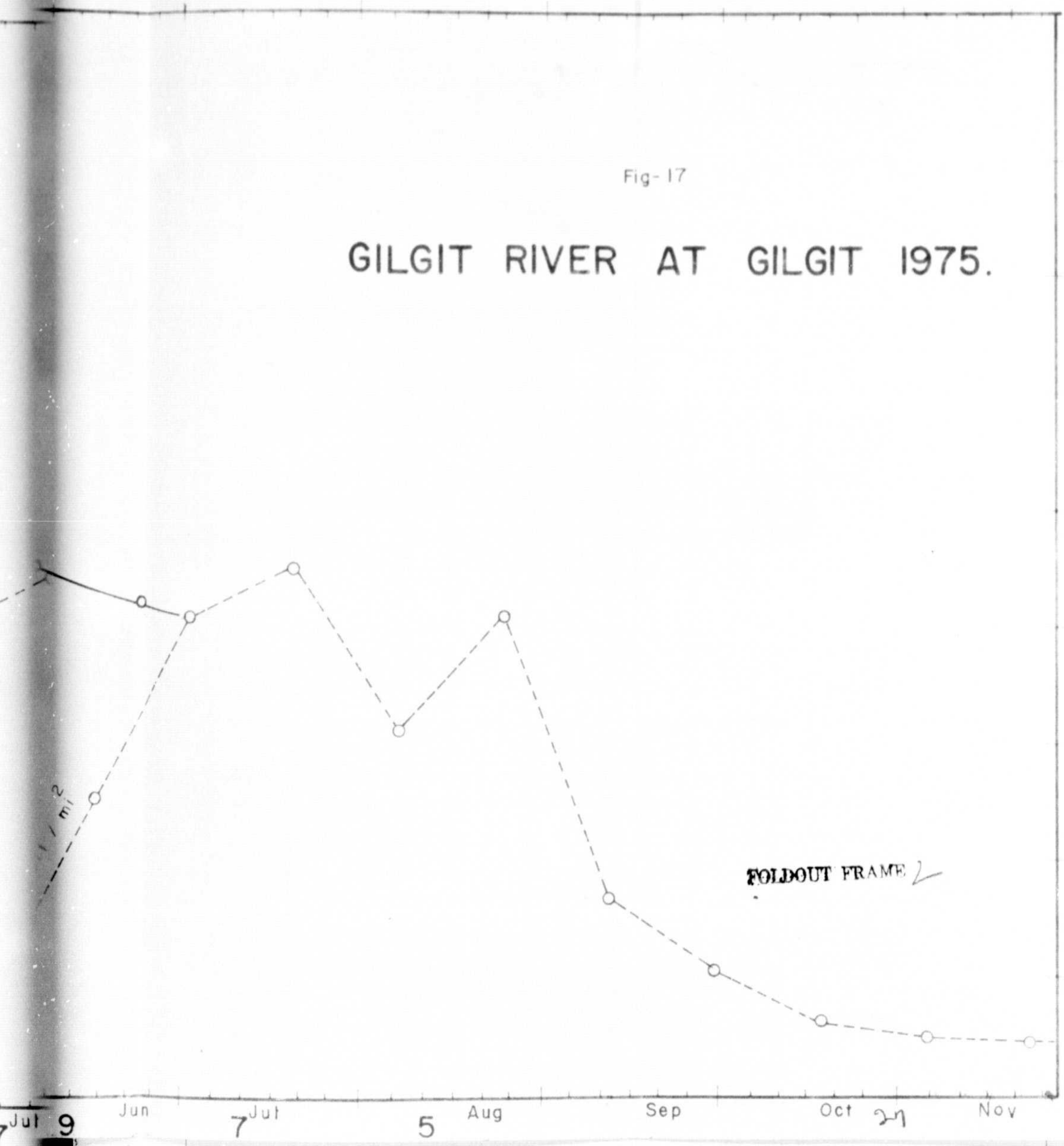

% Snow Cover
100
90
70
60
50
40
30
% Snow Cover
Run Off / mi 2
Feb
Mar
Apr
May
Jun
Jul
FOLDOUT FRAME
1 9 7 9

Fig- 17


GILGIT RIVER AT GILGIT 1975.
18 Day Discharge (cfs) / mile$^2$
100
80
60
40
20
Jun
Jul
Aug
Sep
Oct
Nov
9
7
5
27
FOLDOUT FRAME 2